RACE TO NET ZERO CARBON

A climate emergency guide for new and existing buildings in Australia

Acknowledgement of Country

The authors of this guide acknowledge the Bedegal people, the Traditional Custodians of the Land on which this research was conducted.

We pay our respects to Elders both past and present and extend that respect to all First Nations people of Australia.

Acknowledgements

Authors Deo Prasad, Malay Dave, Aysu Kuru, Philip Oldfield, Lan Ding, Caroline Noller, Baojie He

Title Race to Net Zero Carbon: A Climate Emergency Guide for New and Existing Buildings in Australia v1b

November 2021 (Updated July 2022)

Cover The circle, signifying net zero, comprises both embodied carbon (in green) and operational carbon (in yellow), illustrating that both embodied and operational carbon must be considered in a building's lifecycle.

Guide design Jinga Design

This guide and its benchmarks and targets have been reviewed by industry advisors: Lester Partridge from LCI Consultants, Ian Dixon from GHD and Caroline Pidcock from PIDCOCK. This project also benefited from the data and comments provided by NABERS, Planning Institute of Australia, and Architects Declare Australia, and the review, support and guidance of the Australian Institute of Architects Climate Action and Sustainability Taskforce (CAST) Group. This was a collaborative project undertaken with CAST.

This revision (v1b) has benefited from the review and feedback received from GBCA, NABERS, DeltaQ, Strategy Policy Research, and the Australian Department of Industry, Science, Energy and Resources.

This guide was funded and enabled by the CRC for Low Carbon Living in the post-CRC phase and published by the Low Carbon Institute Pty Ltd. The Low Carbon Institute takes custodial care of CRC for Low Carbon Living publications. Please contact Scientia Professor Deo Prasad AO for further information and approval for use of materials herein.

ISBN 978-0-7334-3997-1

Citation PRASAD, D., DAVE, M., KURU, A., OLDFIELD, P., DING, L., NOLLER, C. & HE, B. 2021. *Race to Net Zero Carbon: A Climate Emergency Guide for New and Existing Buildings in Australia v1b*, Low Carbon Institute (Updated July 2022).

Suggestions of data, methods or feedback for any future editions of the guide can be emailed to d.prasad@unsw.edu.au

CONTENTS

Glossary

ABCB	Australian Building Codes Board
ASBEC	Australian Sustainable Built Environment Council
ATO	Australian Taxation Office
BASIX	Building Sustainability Index
CLCA	Carbon Life Cycle Assessment
CO_2e	Carbon dioxide equivalent
COAG	Council of Australian Governments
CRCLCL	Cooperative Research Centre for Low Carbon Living
EIO	Economic Input-Output Analysis
Embodied carbon	The total of all direct and indirect GHG emissions occurring during the production processes of the building and construction materials. This includes all emissions associated with making the production process equipment, all other supporting business functions for bringing a product to the market, transport of materials to site, and the process of constructing the building itself.
EUI	Energy Use Intensity (kWh/m^2/year)
GBCA	Green Building Council of Australia
GFA	Gross Floor Area: total floor area contained within a building, including the horizontal area of external walls[1]
GHG	Greenhouse gas
HA	Hybrid Analysis
ICMS-3	International Cost Management Standard
kWh	Kilowatt-hour
LCA	Lifecycle Assessment
LCI	Life Cycle Inventory
NABERS	National Australian Built Environment Rating System
NatHERS	Nationwide House Energy Rating Scheme
NCC	National Construction Code
NZC	Net zero carbon. In this guide 'net zero carbon' means 'net zero whole life carbon' (defined below).
NLA	Net Lettable Area: area of a building or industrial park for which, under a lease, a tenant could be charged for occupancy. Generally, it is the floor space contained within a tenancy at each floor level measured from the internal finished surfaces of permanent external walls and permanent internal walls but excluding features such as balconies and verandahs, common use areas, areas less than 1.5 m in height, service areas, and public spaces and thoroughfares.
NTE	Not-to-Exceed
Net zero whole life carbon	A status a building achieves when, and maintains it until, the amount of carbon emissions associated with both operational (scope 1 & 2) and embodied (scope 3) impacts over its nominated service life are net zero or negative.
Operational carbon	The total of all the direct (scope 1) and indirect (scope 2) GHG emission from all energy consumed (operational energy) during the use stage of the building life cycle (including regulated and unregulated/plug loads).[2]
PA	Process Analysis
PCA	Property Council of Australia
RICS	Royal Institution of Chartered Surveyors
Scope of carbon emissions	**Scope 1: Direct emissions from buildings** • Fossil fuel consumption in buildings (boilers, cooking equipment, etc). • Natural and synthetic refrigerants. **Scope 2: Indirect emissions from building energy consumption** • Electricity consumption by: (i) Heating, ventilation, and air conditioning systems (ii) Refrigeration equipment (iii) Lighting and other building services (pumps, lifts, etc). (iv) Equipment and plug loads (computers, appliances, etc). • Energy from heating and cooling services provided by utilities and district plants **Scope 3: Indirect emissions from other sources** • Embodied carbon from materials in the building • Emissions from: (i) water use and sewage treatment (ii) waste sent to landfill
WGBC	World Green Building Council
Whole life carbon	A term for life cycle carbon emissions.
Zero carbon ready	A status of a building that is highly energy efficient and directly uses onsite or offsite generated renewable energy, or alternatively uses an energy supply on track to being fully decarbonised by 2050. This way the building will become a zero carbon (operational) building by 2050 without any further changes to the building or its equipment[3].

Foreword

There is global attention on the pathways to net zero carbon. This guide is well timed to bring together science based evidence on how the built environment can navigate urgently towards a net zero carbon future. It builds on past work on strategies for sustainable low carbon design, the increasing cost effectiveness of both onsite and off site renewable energy and places it in the context of 'climate emergency' thinking to engage built environment professionals in easy to use guidance towards net zero.

It takes a whole of life approach and includes both operational and embodied carbon in its guidance. It draws on Australian climate data and those from local tool managers like the widely recognised NABERS tool in establishing its benchmarks, targets and tools to deliver on its goals.

This guide is kept simple to be easily read and used and is a partner document to the accompanying book being published by MacMillan Palgrave. This book goes into some depth on design strategies and systems and exemplars from around the world, policy snapshots from various countries and developing benchmarks and targets for delivering on net zero carbon buildings globally.

A key element of this guide is a 'architect-client' conversation on trade-offs on when and how net zero carbon will be delivered for that building. The architect may use all the tools at their disposal to bring out 'best performance' at the design time for both new or refurbished buildings. In doing so the matter of onsite generation and outsourcing renewables should be discussed and a time line set for achieving net zero for all buildings. This is a very positive and inclusive approach.

This guide is among the legacy projects of the Co-operative Research Centre for Low Carbon Living (CRCLCL) which I had the pleasure of Chairing. This CRCLCL was a collaboration of a myriad of Australian industries, governments and researchers. It showed that when collaborations at such a scale happen Australian researchers and industry can deliver on practical outcomes and impacts. The CRCLCL developed a significant evidence base for low carbon living policies, knowledge for communities, tools and technologies for the market and world class capacity building. These all help capture economic and social opportunities for Australia.

This project built on past projects of the CRCLCL and was well led by researchers from the University of New South Wales, Sydney. They partnered with the Australian Institute of Architects (CAST Task Group) and other built environment stakeholders in producing the guide for all built environment professions.

Hon Robert Hill AC

Chair of the Board
of the CRC for Low Carbon Living
(2012-2019)

0

INTRODUCTION

Introduction

This guide builds on work previously delivered by ASBEC, GBCA, and others to deliver specific targets for current and future buildings in terms of their **operational** and **embodied carbon** emissions, and presents a pathway towards a **net zero whole life carbon** built environment.

SUMMARY OF A LARGER BOOK

This guide is a summary of a larger book, *Delivering on the Climate Emergency: Towards a Net Zero Carbon Built Environment*, which establishes the detailed methods behind the science-based benchmarks, targets and pathways. The book provides an in-depth and comprehensive collection of strategies and frameworks for verification and reporting net zero carbon performance in the built environment within the international context.

AUSTRALIAN CONTEXT

This guide presents a more easily digestible extract of the book's research, adapted specifically for the Australian context.

This guide analyses and interprets data and findings from multiple sources and outlines a series of current performance benchmarks and climate emergency performance targets for both operational and embodied carbon pathways to net zero.

These target values can be used to set requirements to minimise carbon emissions from the built environment sector, i.e. through legislation, non-regulatory assessment frameworks, design competitions, architecture awards, commitment agreements, tender documents or project contract documents.

WHO IS THIS GUIDE FOR?

- Architects
- Engineers
- Building designers
- Sustainability consultants
- Researchers
- Policy makers
- Design/planning students
- Other built environment practitioners

Guide structure

SECTION 1

A snapshot of the evidence of the climate emergency and why there is an urgent need for action within built environment. The case for rapid decarbonisation in the building sector is outlined along with the scope of carbon emissions in a building's life cycle.

SECTION 2

A brief overview of international and Australian initiatives highlighting the key targets and timelines for different pathways towards a net zero carbon built environment.

SECTION 3

The core of this guide—this study's scope and the operational carbon and the embodied carbon pathways towards net zero. The pathways cover the method used, current performance and carbon targets of different building types studied, along with strategies for achieving net zero. Finally, the proposed net zero whole life carbon pathway with key milestones and timelines is presented on a two-page spread poster.

SECTION 4

Summary of key findings and recommendations for next steps for the Australian built environment sector in terms of rapidly advancing net zero whole life carbon emissions.

APPENDICES

These include templates for implementation use and for collecting project related performance data for the reporting purposes. A method and an example for comparing and combining operational and embodied carbon data is also presented for application on individual projects.

Finally, a list of relevant guides is provided for further reference.

PRACTICAL CONVERSATIONS

This guide strongly recommends a conversation between the client and the designers on *how* to navigate to net zero, and by *when*.

The conversation should include the levels of onsite efficiency to be achieved, the optimisation of onsite renewable energy generation (and storage as appropriate), and how best to balance the remaining carbon emissions with either offsite renewable energy or, as a last resort, eligible and approved carbon offsets for a net zero whole life carbon outcome on every project.

The conversation should lead to a commitment agreement and drive decisions at all project stages from concept design through to construction completion, as well as post-occupancy operations and beyond.

Note

The changes included in this revision (v1b) are:

- Some of the benchmarks and targets also converted from GFA to NLA where applicable;
- Some of the figures and text updated for consistency, clarity, and to include recent developments.

STATEMENT OF LIMITATIONS

The state of climate emergency relates to unprecedented environmental challenges at the interface of, and driven by, the dynamic interplay between primarily three areas: carbon emissions, biodiversity loss, and consumption impacts.

The scope of this guide, however, is limited to carbon emissions from the built environment sector. Similarly, the built environment sector directly or indirectly interacts with the UN's Sustainable Development Goals (SDGs) that define the key challenges the global community needs to address for achieving a more sustainable future for all.[4] Therefore, it is important to balance the role of the built environment across multiple priorities beyond just climate change or carbon. However, considering the scope of this guide is aimed at addressing the climate emergency, the primary focus of this guide remains on energy use and carbon emissions reductions.

The benchmarks and targets established in this guide are based on underlying methodological assumptions and the availability of data at the time of writing. Therefore, it is expected that these benchmarks and targets will be reviewed every three years, as new data and methods emerge. Any suggestions of data, methods or feedback for any future editions of this guide are welcome.

The targets set in this guide are **minimum performance targets**. They should not be used as the norm nor as maximum performance targets. As repeatedly emphasised in this guide, it is not enough to just meet these targets; they are only interim milestones on the pathway to net zero carbon across the entire built environment. In many cases clients and design teams will have the desire and capacity to reduce carbon emissions (embodied and operational) well beyond the targets presented in this guide, which should be encouraged. **Every GHG emission saving is vital as soon as possible.**

1

CLIMATE EMERGENCY: WHY THE URGENCY?

1.1 Global warming trends

Climate emergency:

A situation in which urgent action is required to reduce or halt climate change and avoid potentially irreversible environmental damage resulting from it.[5]

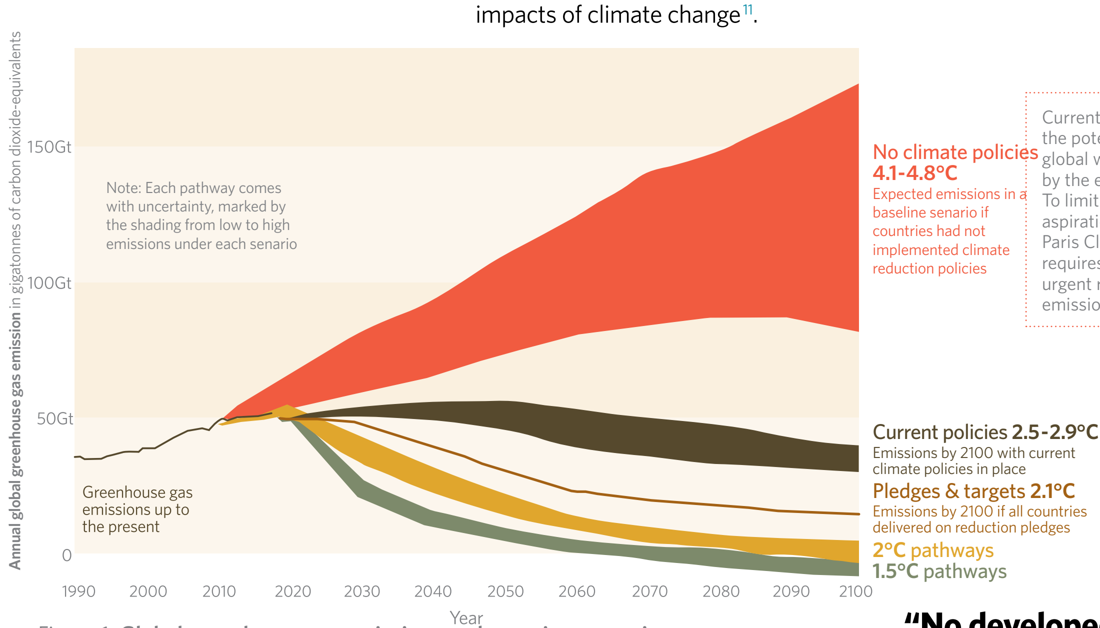
Oxford Dictionaries announced 'climate emergency' as the Oxford word of the year 2019.

The science of climate change is clear and robust, and the evidence of its impact is observed globally. Global temperature trends in recent years have shown unprecedented warming across almost all regions of the planet. The last seven years have been the hottest years on record, while 2020 (tied with 2016) was the hottest year on record for the planet[6,7].

Australia is identified as one of the most vulnerable developed nations to climate change. There is increasing evidence of climate change interacting with underlying natural variability and resulting in substantial increases in the frequency and intensity of extreme weather events[9].

Australia's Nationally Determined Contributions under the Paris Agreement, however, are insufficient and inconsistent with the goal of limiting warming well below 2°C. In fact, Australian and international governments' current policies as of November 2021, even if successfully implemented, would likely contribute to global warming of about 2.7°C[10]. This would have grave consequences for our entire ecosystems, food production, cities and towns, and health and wellbeing. Reaching net zero emissions by 2050 is now an absolutely minimum requirement if we are to avoid the worst impacts of climate change[11].

The latest IPCC Sixth Assessment Report, termed 'a code red for humanity', provides the underpinning evidence, which validates our reason for producing this guide



Current emission trends have the potential to contribute to global warming beyond 4°C by the end of the century. To limit warming to 1.5°C, the aspirational goal under UN's Paris Climate Agreement, requires a substantial and urgent reduction in carbon emissions.

Figure 1: **Global greenhouse gas emissions and warming scenarios**
Source: Our World in Data[8]

"No developed country has more to lose from climate change-fuelled extreme weather, or more to gain as the world transforms to a zero carbon economy, than Australia does."

– Climate Council[12]

1.2 Building sector's carbon contribution

GLOBALLY

The building sector plays a critical role in preventing global warming beyond 1.5°C as buildings and construction are responsible for 38% of global energy-related greenhouse gas emissions[13]. As illustrated in Figure 2, this includes 18% from building operations (scope 1 and 2), 0.5% from the construction process, and at least 20% from materials production (industry). A percentage of 'Other' and 'Transport' emissions is related to the intermediate supply chain transport of materials.

The built environment sector is low hanging fruit for urgent and effective action. While the global community is aiming for net zero by 2050, the building and construction sector has much greater potential and opportunity to deliver quick, deep, and cost-effective greenhouse gas mitigation as compared to many other sectors. With currently available technologies, it is a realistic goal to achieve a substantial emissions reduction by 2030. By tackling the building sector we can make a significant contribution towards the reduction in the overall emissions.

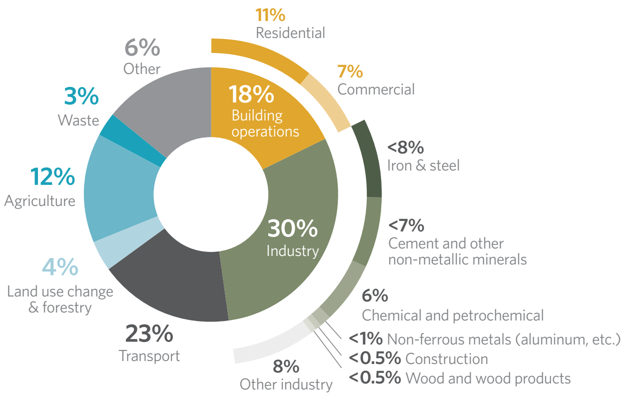


Figure 2: **Global GHG emissions and the life cycle of buildings**
Source: AIA-CLF[13]

IN AUSTRALIA

The building sector in Australia is responsible for one fifth of all emissions.[14] As such, delivering net zero carbon buildings is of great importance for tackling the climate emergency in Australia. The significance of this is more prominent as Australia's building stock is estimated to double by 2050 based on the 2019 level[15].

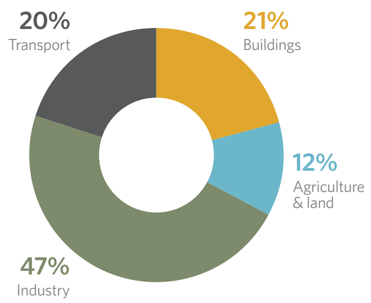


Figure 3: **Australia's emissions by sector, 2018**
Source: ClimateWorks Australia[14]

1.3 Carbon emissions in a building's life cycle

Carbon emissions within the built environment occur across the stages of a building's life cycle. The impact of both operational and embodied emissions must be considered in developing a net zero carbon whole of life strategy.

A life cycle can be defined as "a series of stages through which something (such as an individual, culture, or product) passes during its lifetime".[16] The quantification of the carbon (greenhouse gas) impact of built assets over a service lifetime has been guided by the ISO14044/14067 family of International Standards. EN15978 (sustainability assessment of construction) contributes more by providing a number of life cycle "stages" (or modules as defined in the standard) which comprise of four main stages and seventeen "sub-stages".

Now termed, "whole of life carbon assessment", this includes Stage A (product stage and construction); Stage B (use stage including operations and replacement capital works) and Stage C (end-of-life). Stage D (beyond the life cycle) provides valuable insights about potential benefits, but due to the uncertainty involved, these estimates should be reported separately and not included in calculations.[17] The information in this guide is focused on Stage A (upfront embodied carbon – the product stage and construction stage) and Stage B (operational carbon – the use stage) as shown in Figure 4.

A core objective of ISO14044/67 is to enable "comparability or benchmarking" amongst assessment results to enable the user to understand how one product performs against another. The RICS whole life carbon assessment method[17] defines benchmarking as to "*put all studies on the same basis providing consistency among results, enabling meaningful comparisons at different levels …*" which is fundamental to the property sector. While EN15978 provides a valuable framework to enable measuring building emissions, there are some concerns about a lack of consistency. LETI[18] observes the standard is "*open to interpretation and leads to inconsistency and a lack of comparability between different projects*" and the Carbon Leadership Forum[19] argues that "*There is an urgent need to standardize general building design data and building life cycle assessment data. Alignment in definitions of building area (gross, internal or exterior), building life cycle stages and scopes are critical for comparison*".

Significant advances in definition, measurement method and allocation methods for reporting have occurred in 2021 vastly improving the potential to achieve completeness, accuracy and comparability. Most recently, ICMS-3 Global Consistency in Presenting Construction Life Cycle Costs and Carbon Emissions resolved a basis for global area definition (functional unit) and reporting of emissions by "part of the building" i.e. building/infrastructure element by life cycle stage, addressing these critical shortcomings. The best practice method of whole of life carbon measurement outlined in this guide is based on this seminal standard and refines it for the Australian context in a number of critical areas to achieve significant confidence in benchmark comparability.

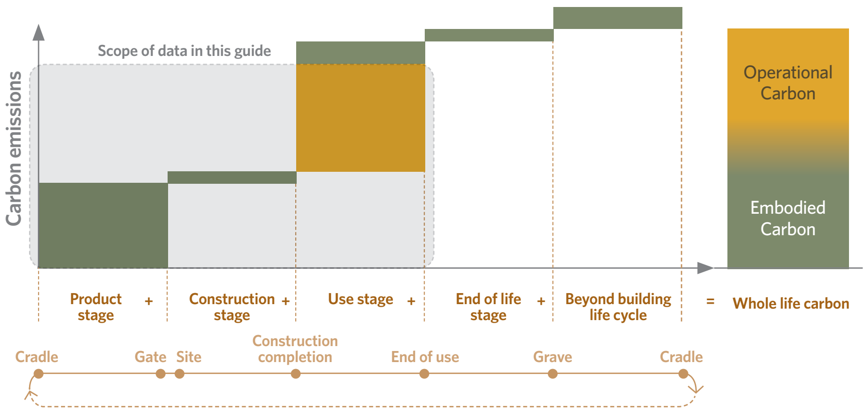


Figure 4: **Scope of carbon emissions across different stages of the building life cycle**

OPERATIONAL CARBON

Operational carbon refers to the total direct (scope 1) and/or indirect (scope 2) GHG emissions from all energy consumed (operational energy) during the use stage of the building life cycle.

It includes both:

- Regulated loads e.g. heating, cooling, ventilation, lighting
- Unregulated/plug loads e.g. ICT equipment, cooking and refrigeration appliances

It is usually expressed in kilograms of CO_2e ($KgCO_2e$).

SCOPE

Operational carbon considered in this guide is limited to scope 2 emissions from electricity generation measured in kWh. We are assuming all buildings to be electrified and onsite fossil fuels eradicated. For each kWh of electricity used, different amounts of GHGs are released into the atmosphere depending on the carbon intensity of the local electricity supply.

CARBON INTENSITIES OF ELECTRICITY

Different states in Australia have different (and increasingly changing) carbon intensities of electricity.
To allow for ease of measurement and comparison we express, in this guide, operational performance at the building scale, measured in terms of Energy Use Intensity (EUI) in $kWh/m^2/year$.

NET ZERO WHOLE LIFE CARBON BUILDING

'Net zero carbon' is a widely used term, however, both Australian[15, 20] and international[21] definitions generally only include operational carbon (scope 1 and 2) and exclude embodied carbon (scope 3), except a couple of recent exceptions.[22, 23]

For example, WGBC's explanation of its definition until 2021 was: "*Net zero carbon is when the amount of carbon dioxide emissions released on an annual basis is zero or negative. Our definition for a net zero carbon building is a highly energy efficient building that is fully powered from onsite and/or offsite renewable sources and offsets*".[24] Now Scope 3 emissions are also included in the WGBC's Net Zero Carbon Buildings Commitment to cover the full scope of Whole Life Carbon.

LETI, on the other hand, clearly states that for them 'net zero carbon' means 'net zero whole life carbon'.[25] This term is also used by RIBA, UKGBC, RICS, among others. It is also consistent with the 'Whole Life Carbon Vision' of the World Green Building Council. GBCA now prefers to use the term 'Climate Positive', which also covers all emission scopes.

Therefore, this guide recommends the use of 'net zero whole life carbon' and, as illustrated in Figure 4, includes both embodied carbon and operational carbon emissions within its scope. Where specifically only operational (scope 1 and 2) or embodied (scope 3) emissions are referred to, 'net zero operational carbon' and 'net zero embodied carbon' terms should be used respectively. The term 'carbon neutral' is typically used in the context of operational carbon only and hence is interchangeable with net zero operational carbon. However, in a whole life carbon framework it should also include scope 3 emissions.

In this guide 'net zero carbon' means 'net zero whole life carbon'. A building achieves a net zero whole life carbon status when, and maintains it until, the amounts of carbon emissions associated with both operational and embodied impacts over its nominated service life are net zero or negative. The 'net' zero status is achieved by offsetting unavoidable carbon emissions through renewable energy generation, preferably through nature-based solutions for carbon removal or other eligible carbon offsets approved under the Climate Active Carbon Neutral Standard for Buildings or equivalent frameworks.

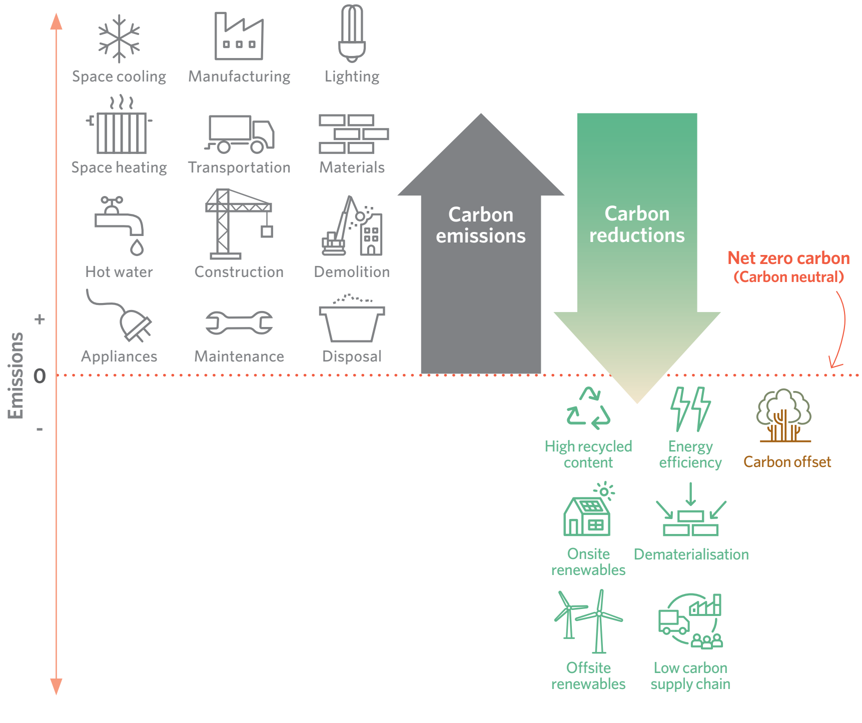


Figure 5: **Strategies to achieve net zero whole life carbon buildings**

EMBODIED CARBON

Embodied carbon refers to the total of all direct and indirect GHG emissions arising from the production of and processing activities for producing materials and constructing the building and use stage material and service inputs into the maintenance and replacement of a building and or infrastructure.

This includes the share of emissions associated with making the production process equipment and all other supporting business functions for bringing a product to the market.

In addition, all emissions associated with transport of materials to site and the process of constructing the building itself are all included within the scope of embodied carbon emissions assessment in this guide.

As illustrated in Figure 4, embodied carbon also includes emissions during other stages and therefore can be measured within different system boundaries, e.g. cradle to gate, cradle to site, cradle to construction completion, cradle to grave, or even cradle to cradle.

However, care must be exercised to avoid double counting, for example in relation to the beyond the building life cycle. Embodied carbon benchmark figures within this guide are cradle to construction completion (typically referred to as upfront carbon or A1-A5 stages in European Standard 15978:2011), which includes product and construction stages, and are expressed in kilograms of CO_2e per m^2 of building type.

2

INITIATIVES AT 2022

towards a net zero carbon
built environment

2.1 Global initiatives: a summary

Internationally, a number of peak bodies, industry associations, governmental and non-governmental organisations have set specific carbon reduction targets and developed pathways towards net zero.

At the time of writing, 34 countries have committed to or proposed net zero emissions targets (most by 2050), and 25 of them have published net zero plans.[26] Some of the key global net zero initiatives for the built environment are summarised below and on the next page.

Table 1: **Summary of key global pathways to net zero carbon**

Operational Carbon Targets

Embodied Carbon Targets

	Short term 2030	Medium term 2040	Long term 2050
Global Alliance for Buildings and Construction — GABC[55]	Net-zero operational ready for new buildings.	Net-zero embodied carbon for new buildings in some countries.	Most new buildings reach net-zero whole life carbon emissions: Most existing buildings operating at net-zero carbon emissions Net-zero embodied carbon for most new buildings.
World Green Building Council — WGBC[21, 27]	Net-zero operational carbon for all new buildings. 40% reduction in embodied carbon for new buildings, infrastructures and renovations.		Net-zero operational carbon for all buildings, including existing buildings. Net-zero embodied carbon for all new buildings, infrastructure and renovations.
RIBA — Royal Institute of British Architects (RIBA)[28]	58% operational energy reduction in new build offices, and 71% reduction in domestic buildings. 40% reduction in embodied carbon for new domestic and office buildings (and NTE built targets[26]). Offset remaining carbon emissions.		
London Energy Transformation Initiative — LETI[18,25]	Net-zero operational carbon for all new buildings. 65% reduction in embodied carbon in all new buildings (and NTE design targets[29]).		All existing homes and non-domestic buildings to be upgraded to net zero carbon.

Operational Carbon Targets

Embodied Carbon Targets

Organisation	Target type	Short term 2030	Medium term 2040	Long term 2050
Architecture 2030[30]	Operational Carbon Targets	100% carbon neutral (using no fossil fuel GHG emitting energy to operate) for all new buildings and major renovations.		
American Institute of Architects[31]	Embodied Carbon Targets	45% reduction by 2025 and 65% by 2030 in embodied carbon for all buildings, infrastructure, and associated materials.	Zero embodied carbon for all buildings, infrastructure, and associated materials.	
International Energy Agency[3]	Operational Carbon Targets	All new buildings are zero carbon ready. 20% of existing buildings retrofitted to be zero carbon ready.	50% of existing buildings retrofitted to zero carbon ready levels.	More than 85% of buildings are zero carbon ready.
	Embodied Carbon Targets	40% reduction per square metre of new floor area.		30% reduction in the use of energy-intensive materials per unit floor area. 50% reduction in the use of cement and steel. 20% relative increase on average building lifetime. 95% reduction in embodied carbon due to NZC emissions in other linked sectors.
Danish Government[32]	Operational Carbon Targets	Phased targets from 2023 reaching 90% of new construction performing better climatically than currently by 2029.		
	Embodied Carbon Targets	Phased targets from 2023 (for all new buildings over 1000m²) until 2029 (for all new buildings of all sizes) requiring LCA calculations to meet specified $CO_2e/m^2/yr$ limit values. More stringent voluntary targets offered at every phase.		

2.2 Australian initiatives: a summary

AUSTRALIAN GOVERNMENT COMMITMENTS

NATIONAL TARGETS

2050: Net zero emissions

2030: 43% reduction on 2005 levels

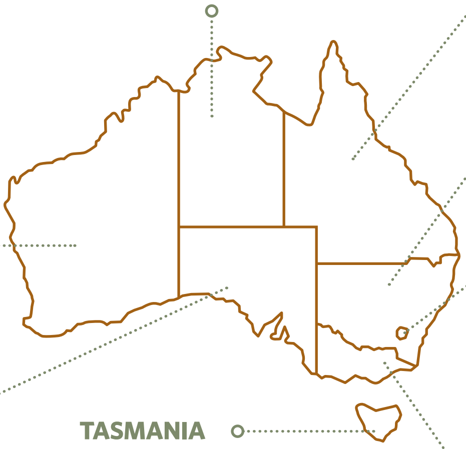
NORTHERN TERRITORY

2050: Net zero emissions

QUEENSLAND

2050: Net zero emissions

2030: 30% reduction on 2005 levels



NEW SOUTH WALES

2050: Net zero emissions

2030: 50% reduction on 2005 levels

WESTERN AUSTRALIA

2050: Net zero emissions

AUSTRALIAN CAPITAL TERRITORY

2045: Net zero emissions

2040: 90-95% reduction

2030: 65-75% reduction

2025: 50-60% reduction on 1990 levels

SOUTH AUSTRALIA

2050: Net zero emissions

2030: 50% reduction on 2005 levels

TASMANIA

2030: Net zero emissions (achieved in 2015)

VICTORIA

2050: Net zero emissions

2030: 45-50% reduction on 2005 levels

2025: 28-33% reduction on 2005 levels

Figure 6: **Australian government initiatives towards net zero emissions**
Source: Adapted from ClimateWorks Australia[33]

LOCAL GOVERNMENT

A recent study of the 57 largest local governments in Australia found that 58% of the councils have a target or aspiration to reduce their operational emissions to net zero by 2050. More than a third of the councils are also aiming to achieve net zero emissions by 2050 for all, or the majority, of their community emissions.[34]

Leading council initiatives

CITY OF SYDNEY

City of Sydney, the first council to become carbon neutral in 2007, declared a Climate Emergency in 2019. It has committed to achieving net zero emissions by 2035 and has developed performance standards and pathways for high performing net zero energy buildings.[35]

CITY OF MELBOURNE

City of Melbourne is running the Climate Change Mitigation Strategy that priorities net-zero carbon buildings and precincts, 100% renewable energy, zero emission transport and the reduction in waste impact to support net-zero operational carbon buildings. City of Melbourne has been operating as a carbon neutral organisation since 2012 and in 2019 declared a Climate Emergency and as a result has committed to net zero emissions target for the municipality by 2040.

Brisbane City Council

City of Brisbane has been carbon-neutral since 2016 and has further targets for reducing its own operational emissions and those of its residents and businesses.

OTHER INITIATIVES

Key initiatives and pathways to net zero by leading organisations include:

The Council of Australian Governments (COAG) Energy Council in 2019 agreed to the Trajectory for Low Energy Buildings. It is a national plan that sets a trajectory towards zero energy (and carbon) ready buildings. As a result, the **National Construction Code** (NCC) is currently undergoing a revision to increase the energy efficiency provisions for residential and commercial buildings from 2022.

Beyond Zero Emissions (BZE) as part of its Zero Carbon Australia project in 2013 produced a Buildings Plan, which was the first comprehensive retrofit plan to transform Australia's building sector to achieve zero operational energy and emissions within 10 years.

NatHERS scheme is built upon a scale of 0-10 stars, where a higher star level corresponds to lower amount of energy demand, and a 10-star house is unlikely to require additional heating or cooling. Work is currently underway to consider raising of the minimum star rating from 6 to 7 stars, to develop NatHERS 'Whole-of-Home' tool to assess and rate the energy performance of the whole house including appliances, and to extend the scheme for existing homes.

ASBEC and ClimateWorks Australia collaboratively developed the 'Built to perform: an industry led pathway to a zero carbon ready building code', with the setting of energy performance targets for different building types across different climates.

ClimateWorks Australia Net Zero Momentum Tracker: It is a central place to track net zero emissions commitments in Australia. It covers different sectors including the property sector. Out of 215 Australian organisations analysed, 18% have committed to net zero by 2050 for at least some emissions.

Climate Council is calling for the Australian Government to commit to at least 75% emissions reduction below 2005 levels, by 2030.

Green Building Council of Australia (GBCA) released in 2018 the 'Carbon Positive Roadmap for the built environment'. The Roadmap noted clear targets for building decarbonisation for new and existing buildings (2030 and 2050 respectively). It also set targets for reductions across all three scopes over time. The purpose of the roadmap was to help industry understand how it should evolve, noted the changes to regulation that would be needed to achieve them, and set targets through Green Star, to create industry knowledge and the conditions for change in the NCC.

Green Star is Australia's most widely used holistic rating tool for the built environment. It covers new buildings, fitouts, precincts, and existing building operations. Green Star Buildings, the latest version for new buildings and major refurbishments, introduced the Climate Positive Pathway. This pathway requires all 6 star rated buildings to be fossil fuel free, highly efficient, powered by renewables and built with low upfront carbon emissions. It also strongly encourages remaining emissions to be offset with nature, removing carbon from the atmosphere.

The Pathway applies to 5 star ratings for projects registered from 2023 onwards, and to 4 star ratings for those that register from 2026 onwards. Any building, finished on or after 2030, must also comply with these requirements. This tiered approach encourages industry to grapple with the challenges over the next decade, enabling it to learn how to deliver climate positive buildings, thus allowing the NCC to make the relevant changes. This approach will also be followed for existing buildings in Green Star Performance, and in new precincts in Green Star Communities. Green Star Homes also follows the principles of the Pathway, though beginning first with net zero carbon operational carbon only. GBCA has signalled a future version will include embodied carbon.

Climate Active, an Australian Government administered program, has developed a voluntary Climate Active Carbon Neutral Standard for Buildings. Using this standard, the Carbon Neutral Certification for buildings is available through the National Australian Built Environment Rating System (NABERS) and the Green Building Council of Australia.

Australian Institute of Architects has called on the Australian Government to establish a national plan towards zero carbon buildings by 2030. This is supported by the Architects Accreditation Council of Australia (AACA) who have released the National Standard of Competency for Architects 2021 (v1.0), which acknowledges the transition to a carbon-neutral built environment as one of the fundamental ethical responsibilities of architectural education and practice.

Australian Architects Declare is the leading group for architects driving action on climate and biodiversity emergency. They have published a short but very useful Guide to Going Carbon Neutral.

The Materials & Embodied Carbon Leaders' Alliance (MECLA) was launched in 2021 to drive reduction in embodied carbon across the building supply chain and transform the building and construction sector to reach net zero emissions.

National Australian Built Environment Rating System (NABERS) program assesses and rates the operational energy performance of key building sectors, including offices and shopping centres. Through the NSW Accelerating Net Zero Buildings Initiative, it is investigating and developing a framework for measuring, benchmarking and certifying emissions from construction and building materials. NABERS will launch a Renewable Energy Indicator later in 2022 which will be provided with every NABERS energy certification. The indicator will transparently display the percentage of energy from renewables.

3

DELIVERING NET ZERO

BENCHMARKS

In order to set the short, mid and long-term carbon reduction targets for delivering a net-zero carbon built environment, it is important to set out embodied and operational carbon benchmarks that consider the variables below.

OPERATIONAL CARBON BENCHMARK KEY VARIABLES

- Climate
- Building classification
- Regional end-use fuel mix
- Building design and its systems

EMBODIED CARBON BENCHMARK KEY VARIABLES

- Building classification
- Functional unit area definition
- Life cycle inventory calculation method
- Overall embodied carbon calculation method
- Scope of building included
- Country of origin

3.1 Scope of methods

The notion of benchmarking is fundamental in progressing action towards net zero carbon for buildings and built environment.

Benchmarking puts "all studies on the same basis providing consistency among results, enabling meaningful comparisons at different levels …".[18]

In absence of this, targets and performance cannot be set or compared.

The scope of analysis and best-practice rules to evolve net zero carbon assessment outcomes to a consistent, credible and transparent level are set out here to enable meaningful benchmarking.

This guide recommends the scope of net zero carbon for Australian buildings to extend to embodied carbon (A1-A5 stages) and operational carbon (B6 stage) for all building types, as defined by the NCC classification system.

3.1.1 KEY VARIABLES IMPACTING OPERATIONAL CARBON BENCHMARKS

Building performance, in terms of operational energy consumption and related carbon emissions, is affected by multiple factors. Some of the key factors considered in this study are:

- **Climate conditions**
  This guide includes building benchmarks of four of the most populated NCC climate zones:

  Climate zone (CZ) 2 – Warm humid summer and mild winter (e.g. Brisbane)

  Climate zone 5 – Warm temperate (e.g. Sydney, Adelaide, Perth)

  Climate zone 6 – Mild temperate (e.g. Melbourne)

  Climate zone 7 – Cool temperate (e.g. Canberra and Hobart)

- **Building type**
  The Australian NCC Building Classification includes ten classes that are combined into five archetypes. This guide covers four major building archetypes. Building classes covered in this guide fall under residential detached and apartment buildings, commercial office and retail buildings, as well as public and institutional buildings.

- **Condition of building**
  The two main building conditions considered within this guide are new buildings and existing buildings undergoing major renovations/ retrofits.

- **Area definitions**
  How the building floor areas are measured can have significant impact on the scope and hence overall operational carbon emissions. GFA is the basis of the Paris Proof Method. However, noting the challenges in comparing GFA, this has been converted to more standardised floor area benchmarks where possible, such as net lettable area (NLA) or Net Floor/habitable area (terminology depending on the building classification).

- **Building design and its systems**
  A building's design features, size, orientation, form, materials, elements and systems used influence the operational carbon performance. In this guide, we have considered these aspects based on the modelling previously performed by CRC for Low Carbon Living in its Building Code Energy Performance Trajectory Final Report.

A number of other factors also impact operational carbon emissions such as microclimatic context, design and construction quality, occupancy level and user behaviour, however these have been considered beyond the scope of this guide. In general, energy and carbon performance of a building is directly associated with energy sources (e.g. gas, electricity). In Australia, each state has different carbon intensity of electricity, due to different fuel mixes used. The application of on-site and off-site renewables can also dramatically reduce the energy demand from the grid and associated emissions. However, this aspect of energy source and fuel mixes also remains out of scope due to the adopted method using national data.

3.1.2 KEY VARIABLES IMPACTING EMBODIED CARBON BENCHMARKS

To achieve a 'complete' and comparable quantification of embodied carbon, it is essential to harmonise six critical variables. The criticality of building typology, area definition, end-use energy type and emissions coefficient is well accepted and understood for operating carbon assessment and benchmarking. Until now however the importance of these variables on the comparability of embodied carbon intensity benchmarks has been overlooked. These are outlined in Table 2.

Table 2: **Key variables impacting embodied carbon benchmarks**

Variable	Possible Impact	Best practice measurement approach
Building Classification	Potentially 100%	The use of the Australian NCC building classification system is fundamental to effecting a valid comparison of embodied carbon intensity for benchmarking purposes. All benchmark figures proposed in this guide are aligned to the Australian NCC classifications.
Functional Unit Area Definition	12-30%+	International Cost Management Standard (ICMS-3) refers to the International Property Measurement Standards as the basis for floor area measurement and reporting. Depending on the building class the difference between Net and Gross floor area can be as low as 12-15% for Class 5 (office) and >30% for Class 6 retail.[56] This guide presents data on a Net Floor Area basis so as to align embodied carbon with operating carbon intensity aligned to the NABERS rating scheme.
Life Cycle Inventory Calculation Method	22-88%+	There are three recognised life cycle inventory computation methods including Process Analysis (PA), Hybrid Analysis (HA) and Economic Input-Output Analysis (EIO). PA has the strength of detail at the factory level but suffers significant truncation errors. EIO is considered "complete" at the national or sub-national level but has weakness with pricing and homogeneity assumptions. HA utilises the strengths of both PA and EIO methods, with the objective of reducing the impact of their weaknesses. The embodied carbon values published in this guide are generally built on HA data values.
Overall Embodied Carbon Calculation Method	22-50%+	This guide recommends a measurement approach which is a "hybrid" one which combines the use of EIO (i.e.value-based $) method and pysical measure of quantities multiplied by EITHER PA or HA LCI coefficients to achieve "completeness" to >95% of the total building value. At feasibility/early-stage design favoring EIO methods, but progressing towards, as far as possible, process measures of final as-built quantities. The choice of LCI data for each quantity input should be noted and adjusted as far as practical to achieve completeness.
Scope of Building Included	40%+	Both RICS method for whole life carbon assessment for the built environment and ICMS-3 have defined the measurement and allocation of embodied carbon to building elements (rather than limiting to mass of material) and to require 95% of the value of a building to be included. In this guide we adopt the elemental allocation definitions for upfront carbon measurement as outlined in both ICMS-3 and RICS whole life carbon assessment for the built environment.
Country of origin	0-50%	It is essential to use basic material LCI data which aligns to the country of origin of the material and appreciate the implication that this will have on the whole building intensity result. For instance, much of the construction steel for Australian projects is sourced from China, where embodied carbon intensity is higher than Australian production. It is essential to select the material kg CO_2e coefficient which represents the country of production of the material.

3.2 Net zero operational carbon pathway

3.2.1 METHODS

The methodology to develop the operational carbon pathway employs two complementary methods: top-down and bottom-up.

TOP-DOWN METHOD

To establish operational carbon performance targets achieving net zero operational carbon in new build and retrofitted buildings in Australia, the Paris Proof Method has been adopted. The Paris Proof Method is a top-down approach and considers the energy supply and demand across the economy at a large scale to calculate the individual building's share of renewable electricity. The Paris Proof Method has been previously used by DGBC, and previously used by UKGBC and LETI to establish what is called 'budget' energy targets for a building sector powered fully by renewable energy.[25, 36, 37]

In order to adapt the Paris Proof Method to the Australian context, we have enlarged its scope to encompass the building classifications as per the NCC and the diverse climate zones within Australia. In its adapted form, the method comprises of several building archetypes and Australian climate zones. The steps to establish operational energy targets using the Paris Proof Method are outlined in Figure 7.

The building archetypes and climate zones included in this guide are dependent on the availability of existing data. Currently in this guide, we have gathered data from government and non-governmental organisations, such as the Council of Australian Governments Baseline Studies, Australian Government Department of the Environment and Energy Commercial and Residential Buildings Baseline, National Australian Built Environment Rating System (NABERS), Nationwide House Energy Rating Scheme (NatHERS), CRC for Low Carbon Living Building Code Energy Performance Trajectory, ClimateWorks Australia, and the Climate Council. It is expected that with the increased availability and access to new data, this method can be expanded to include other building classifications and climate zones in the future.

TOP DOWN APPROACH

Uses comprehensive factors as a basis for decision making and calculations to identify the big picture. In this guide, we look at the building sector across the economy and divide it into its individual sub categories based on building type, location and climate.

PARIS PROOF METHOD

The top-down method is derived from determining the energy supply and demand across the economy at a large scale to calculate the individual building's share of renewable electricity. The Paris Proof Method has been developed by DGBC, and previously used by UKGBC and LETI to establish what is called 'budget' energy targets for a building sector powered fully by renewable energy.

1. Calculate the electricity equivalent of the total current energy demand in the building stock (TWhe)
2. Estimate renewable energy supply in the future (TWhe)
3. Determine the energy demand reduction required to balance the future demand and future renewable energy supply (%)
4. Determine the energy demand of the building stock proportioned across the economy (TWhe)
5. Allocate the available energy supply to different building types based on their energy use proportion within the building stock (commercial and residential TWhe)
6. Determine the total floorspace per building archetype in the future (m^2)
7. Calculate the maximum average energy consumption per square meter per building archetype in the future (kWh/m^2)

Figure 7: **Steps of the top-down approach**

BOTTOM-UP METHOD

The bottom-up method used in this guide looks at the extensive modelling data and simulation results available at the *Building Code Energy Performance Trajectory – Final Technical Report* by the CRC for Low Carbon Living (Fig 9).[38] The bottom-up modelling method is taken into account in order to have an outline of the performance of different building archetypes based on various Australian climate zones. The modelling performed in the Energy Performance Trajectory Project is comprehensive and contains recent information in respect to the current legislation.

> **BOTTOM UP APPROACH**
>
> Focuses on the individual parameters and components brought together to provide an overall understanding. In this guide, we look at individually modelled building archetypes in different climates to have an overall understanding of the building stock.

The modelling performed by the CRC for Low Carbon Living in the Building Code Energy Trajectory Project examined multiple building archetypes located in four Australian climate zones covering the country's largest population centres.[38]

This project accompanies the Built to Perform report that provides details on the underlying assumptions and results from the work.[15] The steps are also outlined in Figure 8.

7 Presenting the final trajectory in 3-year step periods

6 Defining the performance at fixed points in the future through a 5-year step period

5 Multi-dimensional trajectory analysis of the modelling and simulation results

4 Single-dimensional trajectory analysis of the modelling and simulation results

3 Investigating a range of energy efficiency improvements to the building fabric and fixed equipment and on-site renewables

2 Simulating the performance of the modelled representative building archetypes

1 Modelling representative building archetypes to produce simulation models

Figure 8: **Steps of the bottom-up approach**

COMBINED METHOD TO ESTABLISH EUI PERFORMANCE TARGETS

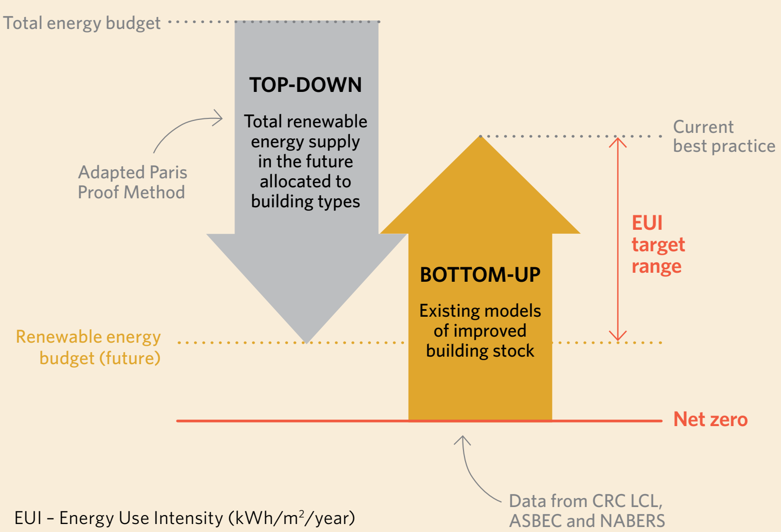


Figure 9: **Method of generating EUI targets**

The combined method to deliver net zero operational carbon buildings is a mixed approach of the top-down Paris Proof Method and the bottom-up modelling method. The combination of methods defines the range for minimum EUI target. The range is determined by taking the lower and upper bands that the top-down and bottom-up methods provide. It is important to note that the range these methods provide is defined as a positive EUI.

However, the actual target for delivering net zero operational carbon is net zero emissions. Therefore, the range provided aims at establishing stringent EUI targets for highly energy efficient buildings (effectively net zero carbon ready buildings) to then achieve net zero emissions through incorporating energy generation from on- or off-site renewable sources and carbon offsetting.

3.2.2 CURRENT PERFORMANCE AND CLIMATE EMERGENCY TARGETS

Table 3: **Australian Climate Emergency Targets for Operational Carbon Performance for New Buildings and Major Renovations**

Building type	Climate	Average existing building EUI[39,40]*	Current practice (2022)	2030 Operational Carbon Performance Targets: Minimum performance targets (EUI GFA*)	Min. performance targets (EUI NFA* if applicable)	Performance equivalent to	Operational carbon target
Class 1: Detached house	National	42.6	NatHERS 7 star#	11-36		NatHERS# or Green Star Homes equivalent with 100% Green Power	**NET ZERO** with 100% Green Power
	CZ 2			11-35			
	CZ 5			11-35			
	CZ 6			11-36			
	CZ 7			11-37			
Class 1: Semi-detached house	National	44.8	NatHERS 7 star#	11-34			
	CZ 2			10-34			
	CZ 5			10-33			
	CZ 6			11-35			
	CZ 7			11-36			
Class 2: Residential apartment	National	69.2	NatHERS 7 star#	29-55	23-44	NatHERS#, NABERS or Green Star Buildings rating with 100% Green Power	
	CZ 2			29-54	23-43		
	CZ 5			29-54	23-43		
	CZ 6			29-56	23-44		
	CZ 7			30-57	24-45		
Class 3: Hotel	National	459	NABERS 3.5 star	71-77		NABERS or Green Star Buildings rating with 100% Green Power	
	CZ 2			76-81			
	CZ 5			73-77			
	CZ 6			69-74			
	CZ 7			69-78			
Class 5: Office	National	138	NABERS 5.5 star	63-67	55-58		
	CZ 2			69-77	60-67		
	CZ 5			66-72	57-63		
	CZ 6			56-68	49-59		
	CZ 7			57-68	49-59		
Class 6: Retail	National	414	NABERS 3.5 star	70-181	49-126		
	CZ 2			75-195	52-136		
	CZ 5			69-179	48-125		
	CZ 6			67-173	46-121		
	CZ 7			68-175	47-122		
Class 9a: Hospital	National	465	Section J of the NCC	68-115		Green Star Buildings rating with 100% Green Power	
	CZ 2			67-113			
	CZ 5			63-108			
	CZ 6			72-121			
	CZ 7			71-119			
Class 9b: Educational building	National	199	Section J of the NCC	29-36			
	CZ 2			33-43			
	CZ 5			29-31			
	CZ 6			20-30			
	CZ 7			32-40			
Class 9b: Public assembly building	National	98	Section J of the NCC	44-48			
	CZ 2			44-48			
	CZ 5			44-48			
	CZ 6			44-48			
	CZ 7			44-48			

* Energy Use Intensity in kWh/m²GFA/yr for whole building (including plug loads)

The average existing building EUI is based on the reports and calculators published by the Council of Australian Governments and the Australian Government Department of Climate Change, Energy, Environment and Water that determine code-compliant baseline energy consumption figures for 2020 based on the National Construction Code of Australia.

Area definition: GFA used for all buildings due to it being the basis of the Paris Proof Method. Where applicable, this has been converted to other floor area benchmarks such as net lettable area (NLA).

\# NatHERS assesses heating and cooling energy only and excludes other energy uses. Where relevant, whole building energy use equivalent to NSW's BASIX rating scheme can be used with NatHERS.

AIM
All new buildings and major renovations achieve net zero operational carbon by 2030

Note: All buildings are assumed to be fully electrified and onsite fossil fuels eradicated. The calculations carried out to generate the EUI performance targets in this guide include different building conditions (new built and major renovations), various Australian climate zones (zones 2, 5, 6, 7; referred to as CZ in this table) and several building archetypes (building classes 1, 2, 5, 6, 7, 9a, 9b) as per NCC.

The calculation method considers GFA to determine EUI performance targets. In doing so, the targets defined in this guide **are different, and hence not comparable, to some other local and global EUI targets**.

For example, for commercial office buildings, LETI defines a single target for an entire country for GFA and NLA. In addition, City of Sydney, defines targets for the specific context, geographical location, and climate of the City of Sydney for base building or whole building depending on building types.[35]

3.2.3 STRATEGIES TOWARDS NET ZERO OPERATIONAL CARBON

Strategies can be broadly categorised into three priorities.

Demand reduction through energy efficiency must be considered the first priority in any building as it includes a large number of strategies offering significant operational carbon reduction potential. Maximising onsite low carbon energy supply, and then offsite supply, of renewables should be the subsequent options to meet the remaining energy demand (see Table 4 below).

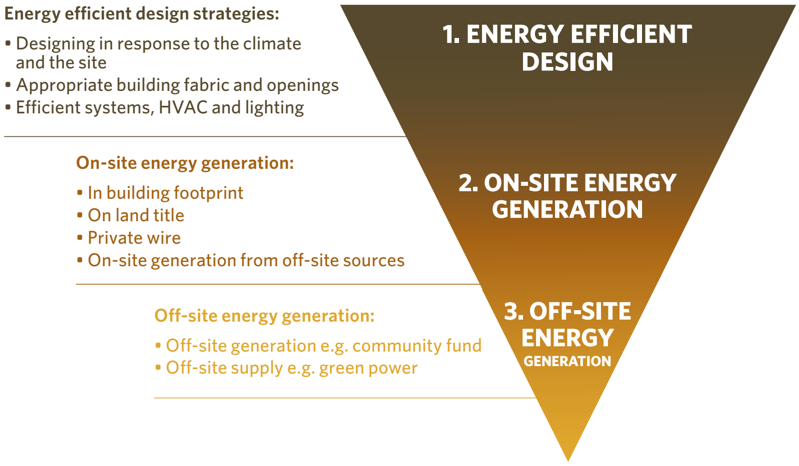


Figure 10: **Strategies for achieving net zero operational carbon**
Source: Adapted from ASBEC[41]

Table 4: **Key strategies for achieving net zero operational carbon performance** Source: Adapted from CRCLCL guides[42] (see Appendix A.3)

ENERGY EFFICIENCY

NEW BUILDINGS

1. Designing in response to climate and site

Commercial and residential buildings

- Climate-responsiveness
- Appropriate external surface colour and surrounding vegetation

2. Building size, form and orientation

Commercial and residential buildings

- Optimum building size
- Appropriate orientation and efficient form

3. Efficient building fabric and openings

Commercial buildings

- Efficient and appropriate glazing and shading
- Appropriate insulation
- Appropriate airtightness

Residential buildings

- Efficient and appropriate glazing and shading
- Appropriate insulation and airtightness
- Providing natural ventilation
- Appropriate levels of thermal mass
- Avoiding thermal bridges

4. Efficient HVAC and lighting

Commercial buildings

- Efficient ventilation, heating and cooling
- Using control systems
- Increasing range for setpoints
- Efficient artificial lighting and improving daylighting

Residential buildings

- Efficient hot water heating
- Using passive heating and cooling
- Efficient artificial lighting
- Efficient appliances
- Using smart home systems

RETROFITS

1. Building fabric and openings upgrades

Commercial buildings

- Improving or adding insulation
- Implementing cool and green roofs
- Using advanced glazing

Residential buildings

- Deciduous planting
- Improving natural ventilation through openings
- Window upgrades
- Providing external window shading
- Improving or adding insulation
- Improving airtightness
- Adding thermal mass

2. HVAC and lighting upgrades

Commercial buildings

- HVAC upgrades
- Using combined heat and power plants
- Using high-efficiency lighting
- Daylight enhancing design and systems
- Using high-efficiency equipment
- Building automation and controls

Residential buildings

- Hot water systems upgrades
- Air conditioning upgrades
- Using ceiling fans
- Appliances upgrades
- Using high-efficiency lighting
- Energy monitoring

ENERGY GENERATION

NEW BUILDINGS & RETROFITS

Commercial and residential buildings

1. Generating energy from on-site renewables

- Photovoltaic systems

2. Generating energy from off-site renewables

- Precinct level energy generation
- Power Purchase Agreement (PPA)
- Green power

3. Energy storage

- Electric storage hot water systems
- Distributed energy storage systems

3.2.3 STRATEGIES TOWARDS NET ZERO OPERATIONAL CARBON continued

The potential carbon improvement that can be achieved through energy efficiency strategies, reduced energy use, energy generation and to meet and even exceed net zero operation carbon targets are illustrated in Figure 11 and 12 below. These strategies aim to provide a quantitative indication of how operational carbon savings can be made beyond current and best performance practices. The proportions presented are indicative of what is potentially the highest percentage possible at present and will vary depending on the climate, design and systems.

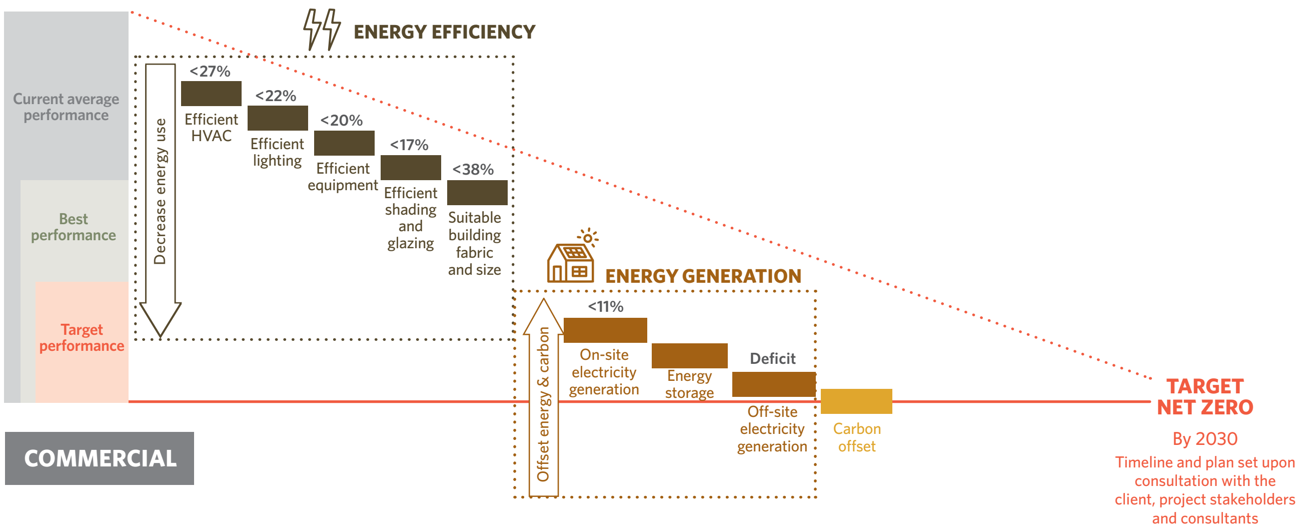


Figure 11: **Commercial Buildings: Strategies to achieve net zero operational carbon** Source: Based on CRCLCL[43, 44] and BZE[45]

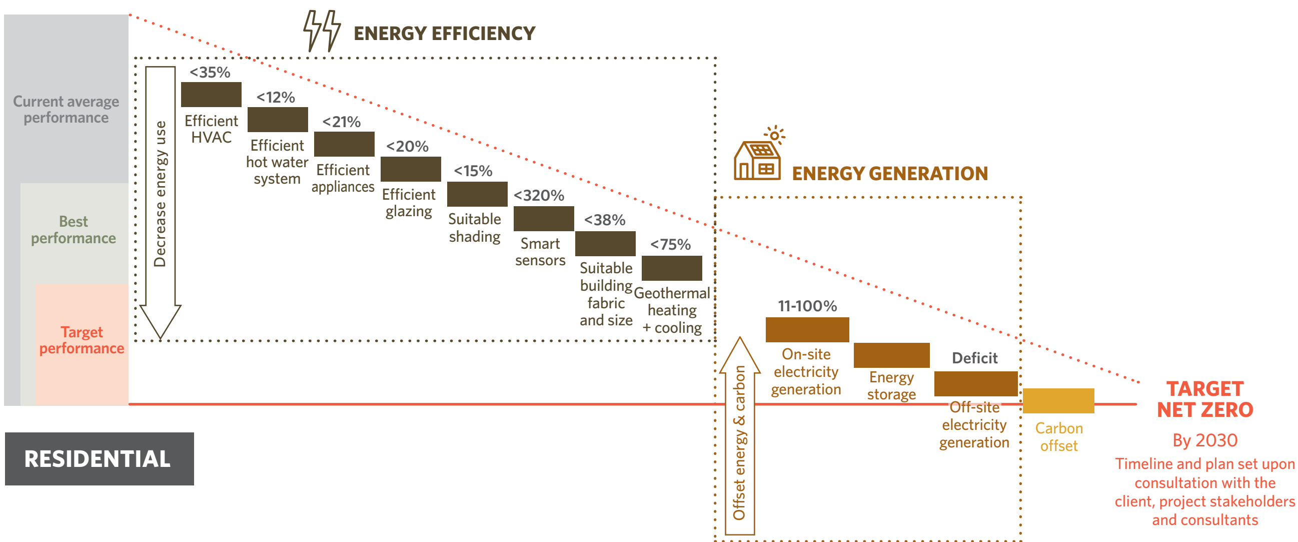


Figure 12: **Residential Buildings: Strategies to achieve net zero operational carbon** Source: Based on CRCLCL[46, 47] and BZE[45]

3.3 Net zero embodied carbon pathway

3.3.1 METHODS

The scope for embodied carbon assessment for buildings in this guide is limited to the upfront stage (A1-A5). As the construction industry's capacity to achieve quality, consistency and completeness for upfront embodied carbon assessment increases, there will be a basis for extending benchmarks to life cycle stages B (refurbishment) and C (end of life).

The problem of comparability in life cycle cost planning in engineering and cost management fields is well known. The reliable estimating, modelling and scenarios of life cycle cost of complex products (such as buildings and infrastructure) is limited and highly uncertain (in both scale and timing) owing to the individual nature of assumptions with limited information at the early stage. Unless mandatory life cycle operating (B1); maintenance (B2,3) and renewal/replacement (B4,5) inputs and cycles for every aspect of a building or infrastructure are defined, any result is subject to uncertainty and limited to the opinion of the study proponent.

As noted in section 1.3, the Carbon Leadership Forum's (CLF) seminal Embodied Carbon Benchmark Study[19] concludes "there is an urgent need to standardise general building design data [including area, life cycle and materials scope], critical for comparison" In preparing this guide the authors have completed an international review of noted published benchmarks and studies and have made an attempt to adjust the findings for the critical variables outlined in Table 2 (refer to Figures 15 and 16 in Section 3.3.2).

The publication of the ICMS-3 standard in 2021, substantially progressed best practice measurement methods and elemental allocation requirements for Embodied Carbon. ICMS-3 in particular has assisted by defining mandatory reporting of 1) total GHG emissions and 2) emissions intensity in terms of both Net Floor and Gross Floor area (or in ISO14044 terms, the Functional Units). It is also important to note the inclusion of Preliminaries (i.e. all inputs and costs into the building process; waste, onsite energy, sheds etc) and the mandatory exclusion of any "sequestration" from the total GHG emissions reported.

In this guide we outline an approach to a method of embodied carbon measurement, that considers two critical areas to address key method inconsistencies including:

1) the adoption of the NCC building classification system as the basis for benchmark comparison and
2) the use of Combined LCA and the valuable role it and EIO methods have to play in feasibility, early and concept level design stages.

Figure 18 (on page 37) demonstrates the most suitable LCA approaches to apply across the design process. The problem of LCI method is not resolved so it is recommended that LCI method is clearly disclosed, as is the inventory source, and evidence to support relevant country of origin data is used for the study.

The method recommended by this guide uses Combined LCA methods from feasibility to as-built for completeness and consistency. In summary the main methodological steps include:

1. Definition	2. Building Scope	3. Combined LCA Methodology	4. Embodied Carbon Impact Assessment	5. Interpretation & Communication
• Use NCC classification to define building type. • Define the Net and Gross floor area Functional Unit definition using the relevant IPMS building class standard. • Define service-life periods using Australian Tax Office (ATO) service life outlined in series 66110 to 67200.	• Use ICMS-3 for impact allocation across all main and sub-elements (building and infrastructure) for Upfront Carbon. • Ensure that information is available in physical units or dollars to cover a minimum 95% of the building / infrastructure value. • Include all works within the site boundary (i.e. Not just the building but all ground and external works).	• Use the project feasibility or early stage cost plan to establish both money and physical quantities, where available. • Use EIO coefficients x money where quantities cannot be established and material LCI coefficients x quantities where available to achieve a combined LCA assessment for 95% of the project. • Ensure that the material LCI carbon coefficients are country relevant.	• Calculate to establish the Reference case Total A1-A5 embodied carbon by the sum of $ x EIO coefficient plus physical quantities x materials coefficient for the reference design on a "typical business as usual" basis (i.e design as is code compliant and with no advanced materials / recycled content, etc). • Model reduction potential alternatives through the systemic application of design efficiencies, low carbon materials substitutions, recycle and or repurposed materials or elements. • Normalise all resulting total embodied carbon values in Kilograms of CO2e in absolute terms and then normalize to both Net and Gross floor area by element consistent with ICMS-3 reporting tables.	• Compare the results in $kgCO_2e/m^2$ NLA to the guide's recommended performance bands in Figure 14 to establish whether the scenarios resolved meet the Climate Emergency pathway and, if not, then understand which elements of the design are driving the impact and work to resolve performance pathways to achieve the targets.

Figure 13: **Method for benchmarking and comparing embodied carbon performance**

3.3.2 CURRENT PERFORMANCE

This section presents Australian embodied carbon emissions for different buildings (see Figure 14). These have been calculated using the previous defined method and The Footprint Company's large dataset, which covers over 1700 whole building embodied carbon assessments. These buildings are categorised into a variety of typologies with over 30 data points for each typology[48]. Figure 14 presents the averages of these data points. These represent the average embodied carbon values in Australian construction practice consistent with NCC Section J 2018.

> The ranges 'Good' and 'Poor' reflect performance which is 40% better and worse compared to the 'average' performance.

Values at the lower range (i.e. better than average) generally represent project results where there has been the systemic application of low embodied carbon design principles (and circular economy) such as, build less/retain, recycled content, low carbon supply chain, etc.

For Class 2, 5 and 6 the range is large and reflects the additional sub-categorisation within the building class. For example, class 5, offices in Australia can be sub-categorised, Class A (premium); A; B and C. These sub-classifications have a direct bearing on the resultant embodied carbon intensity due to a variety of quality and servicing standards defined by the Property Council of Australia (PCA).

For example, the lift servicing (number, speed, quality etc.) significantly increases between the classes and has a direct impact on the embodied carbon content of lift servicing (in many cases by a factor of up to 100%). This is repeated for most elements of the building. Thus, Premium A buildings will always have an embodied carbon intensity that is above the average value and as such, in a carbon constrained world, , it would suggest the opportunity for a further sustainability review of the PCA property standards, to consider the issue and possibly incorporate the proposed embodied carbon quotas in the environmental quality performance matrix.[49]

Typical Embodied Carbon values in Australian buildings kg CO_2e/m^2 NLA (A1-A5)

Class	Building type	Good	Average	Poor
1	Residential (Timber/Brick Veneer)	762	1,270	1,778
1	Residential (Concrete/Brick)	878	1,464	2,050
2	Multi-Residential (Low/Mid Rise <25m)	1,185	1,975	2,765
2	Multi-Residential (High Rise >25m)	2,012	3,354	4,696
5	Office (A Grade)	2,019	3,365	4,711
5	Office Fitout	1,128	1,880	2,632
6	Retail (Regional/Sub-Regional)	1,958	3,264	4,570
6	Food Retail Fitout	529	882	1,235
6	Non-food Retail Fitout	337	562	787
7	Carpark (Basement/Deck)	1,207	2,012	2,817

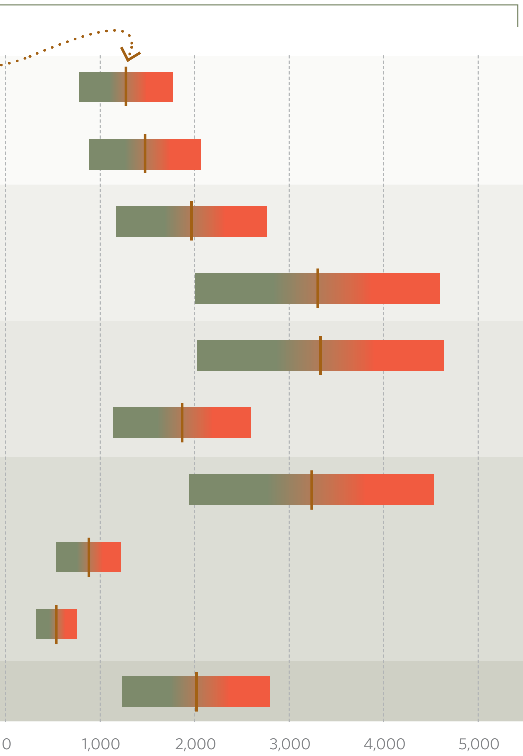


Figure 14**: Typical Australian embodied carbon values by building classification**

Comparing our data with other international studies

In preparing this guide the authors have completed an international review of noted published embodied carbon benchmarks and studies. There has then been an attempt to adjust these findings for the critical variables outlined in Table 2 on page 27. This is outlined in Figures 15 and 16 below.

The figures for embodied carbon presented in this guide are higher than those found in the literature and other benchmarks. Figures 15 and 16 show the embodied carbon intensity (representing average practice), from a number of sources for Residential (Class 1 & 2) and Commercial (Class 5 & 6) buildings respectively, on a per square meter basis for the life cycle stages of A1-A5. These are colour coded to better highlight the building element scope included within the "benchmark" values.

> It can be seen that other published data on embodied carbon is lower than the benchmarks here. This is due to the completeness of the materials included in the analysis in this guide, and the Hybrid/Hybrid (both hybrid LCI data and a hybrid life cycle analysis) method used (for example, including preliminaries). As such, care should be taken when using any embodied carbon benchmarks, to ensure comparisons use consistent methods and boundaries.

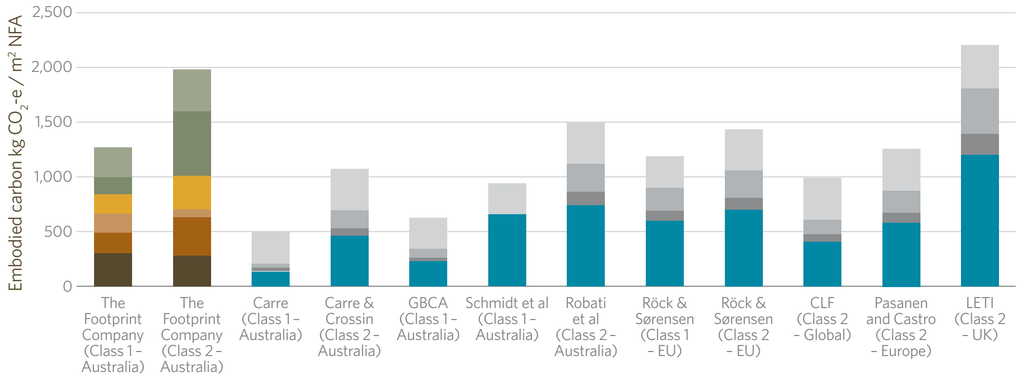
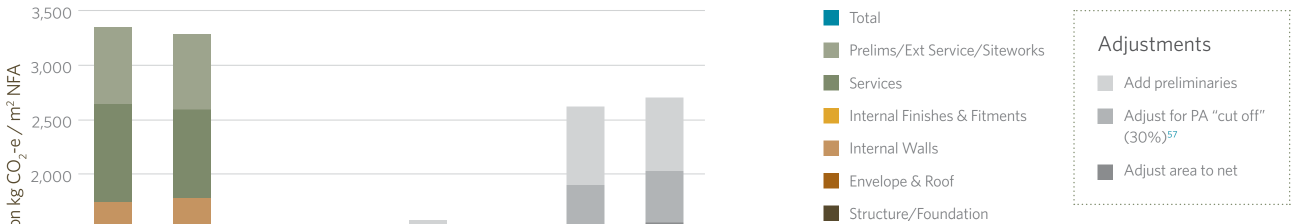


Figure 15: **International residential (Class 1 & 2) embodied carbon benchmark (Average practice)**
Sources: The Footprint Company[48], Carre[50], GBCA[51], Schmidt et al.[52], Röck et al.[53], CLF[19], Pasanen and Castro[54], and LETI[18]



Area definitions:

NHA = Net habitable area: Internal conditioned habitable space excluding common areas and services areas

NLA = Net lettable area: Area of a building for which a tenant could be charged for occupancy

GDA = Gross dwelling area: Gross internal dwelling area plus external un-enclosed balcony areas (higher than NHA)

GFA = Gross floor area: Total floor area contained within a building, including the area of external walls (can be up to 30% higher than NLA)

Figure 16: **International residential (Class 5 & 6) embodied carbon benchmark (Average practice)**
Sources: The Footprint Company[48], Pasanen and Castro[54], GBCA[51], Röck et al.[53], CLF[19], and LETI[18]

3.3.3 CLIMATE EMERGENCY TARGETS

We propose a stepped approach to developing interim targets as the pathway towards a 2040 net zero embodied carbon goal. This approach considers the current Australian average embodied carbon benchmark and the reductions possible through the application of advanced circular economy practice available in the building industry today. The recommended not-to-exceed (NTE) targets towards net zero embodied carbon for all new buildings and major renovations in Australia are outlined on this page.

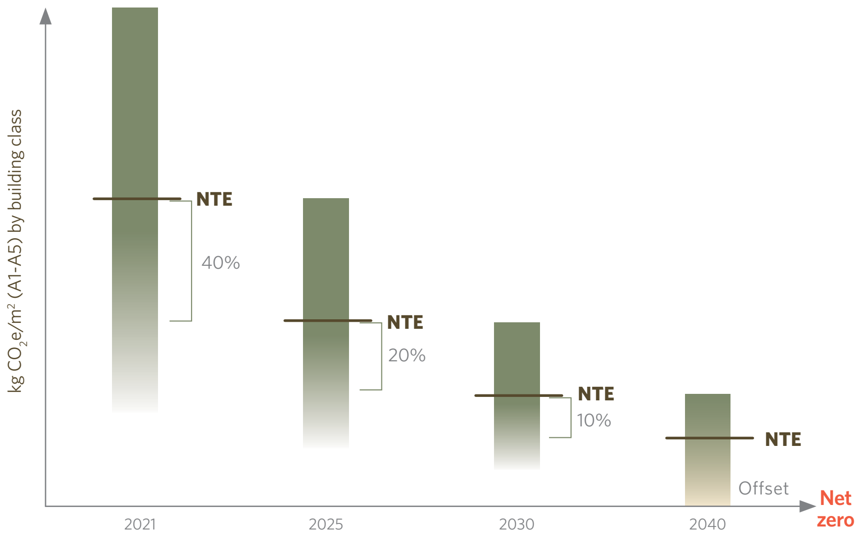


Figure 17: **Proposed approach to interim embodied carbon targets**

2021	2025	2030	2040
Immediately adopt the current average embodied carbon value (kgCO_2e/m² A1-A5 absolute) as the voluntary NTE quota for all building types. Where possible, aim for a further 40% improvement.	Ratchet down the maximum NTE embodied carbon quotas to 40% below the average in 2021.	Further reduce the maximum NTE embodied carbon quotas to 20% below the average in 2025.	Achieve net zero embodied carbon for all new buildings and major renovations through the use of eligible carbon offsets either on or off site.
Adopt and apply this method of measurement and reporting to support disclosure of performance in compliance against the targets. Undertake independent third party review if desired, to increase assurance of results, ensuring that peer review is consistent with the requirements of ISO14044.	Measure and report (mandatory) for disclosure of performance for all new buildings and major renovations.	Review the reported outcomes and revise the NTE levels based on new data.	

Table 5: **Embodied carbon performance targets for new buildings and major renovations**

		Embodied Carbon NTE* Minimum Performance Targets			
Class	Building type	2021	2025ˆ	2030ˆ	2040ˆ
1	Residential (Timber/Brick Veneer)	1,270	762	610	Net zero with eligible offsets
1	Residential (Concrete/Brick)	1,464	878	703	
2	Multi-Residential (Low/Mid Rise <25m)	1,975	1,185	948	
2	Multi-Residential (High Rise >25m)	3,354	2,012	1,610	
5	Office (A Grade)	3,365	2,019	1,615	
5	Office Fitout	1,880	1,128	902	
6	Retail (Regional/Sub-Regional)	3,264	1,958	1,567	
6	Food Retail Fitout	882	529	423	
6	Non-food Retail Fitout	562	337	270	
7	Carpark (Basement/Deck)	2,012	1,207	966	

* Not-to-Exceed targets in kgCO_2e/m² NLA (A1-A5) represent maximum allowable embodied carbon
ˆ Mandatory reporting

3.3.4 STRATEGIES TOWARDS NET ZERO EMBODIED CARBON

A net zero embodied carbon building applies circular economy and design mitigation strategies to the maximum possible extent to achieve the lowest feasible upfront embodied carbon emission (A1-A5). The residual emissions are then fully offset upon achieving practical completion. Offsets can be achieved on or off-site with a preference for on-site. Figure 18 below shows the order of magnitude of embodied carbon mitigation possible across the major design phases, by applying a number of key principles and strategies.

Consider investigating whether on-site embodied carbon offsetting is possible. To do this, annualise the residual A1-A5 emissions by life span in years, consistent with the building typology (being guided by the Australian Tax Office depreciation schedules). Once the annual $kgCO_2e$ of A1-A5 is determined establish whether an equivalent can be generated on-site.

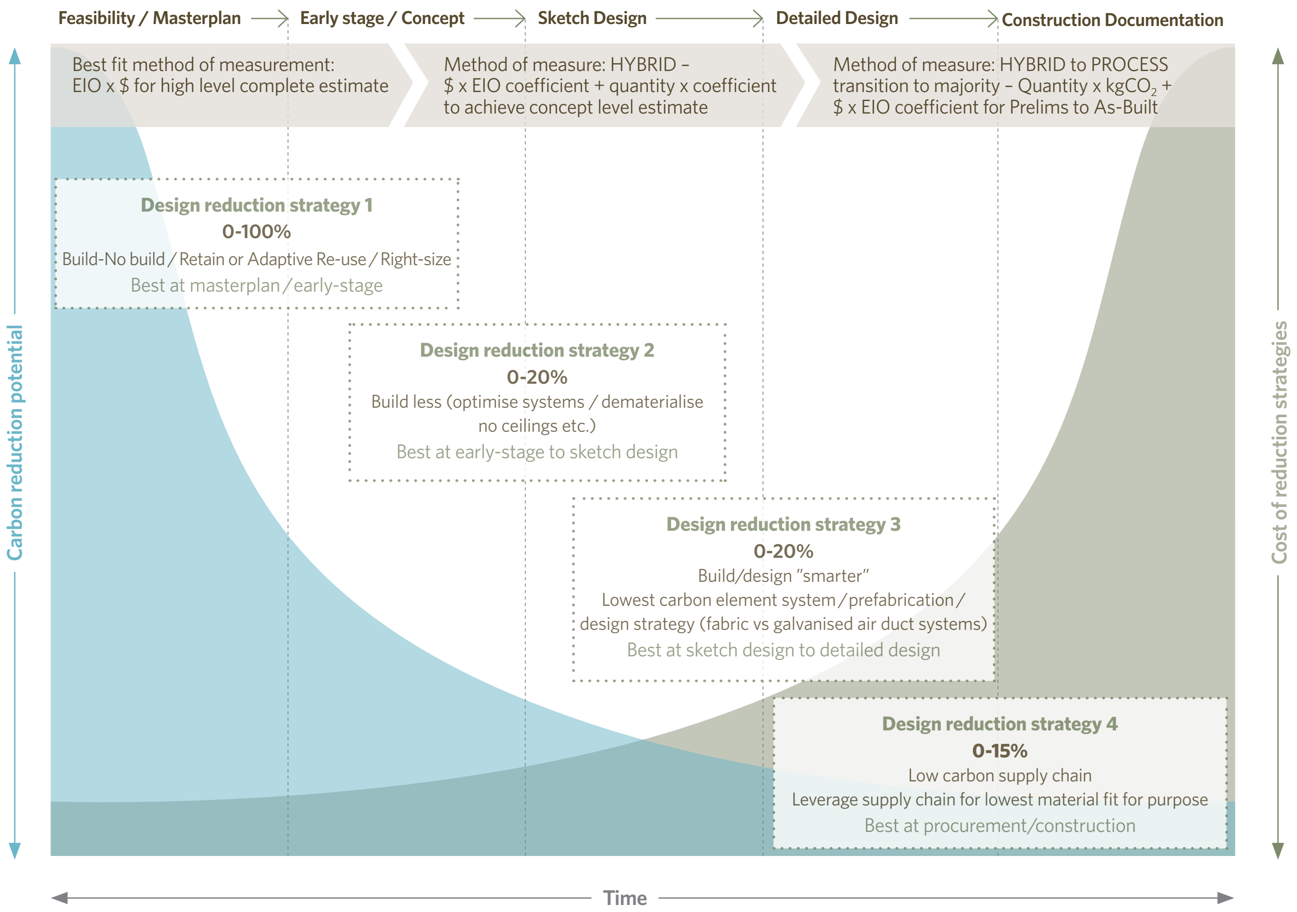


Figure 18: **Embodied carbon reduction potential by design stage and recommended measurement method**

3.3.4 STRATEGIES TOWARDS NET ZERO EMBODIED CARBON continued

The strategies for achieving net zero embodied carbon can be organised under four general categories. Table 6 below summarises these principle strategies and provides an indication of the order of magnitude of mitigation benefit possible. A brief narrative of the sorts of specific strategies to investigate and the best design phase to apply these principles to achieve maximum outcome is also outlined. Figure 18 on the previous page demonstrates the principles overlaid with cost/time and carbon benefit order of magnitude. After minimising the embodied carbon through all four strategies, the residual emissions can be offset using accredited carbon offset schemes.

Table 6: **Key strategies to apply in sequence to maximise the embodied carbon reduction potential**

NO BUILD / BUILD / RIGHT-SIZE	BUILD LESS / DEMATERIALISE	BUILD "SMARTER"	LEVERAGE SUPPLY CHAIN AND PROCUREMENT METHODS
(**0-100%**) – only applicable at early stage or end-of-life incorporates adaptive re-use and or retention of existing whether it is structure, envelope or potentially many services elements.	(**0-20%**) – best used in early stage and concept design stages - look for system optimisation (services in particular), floor to floor height reductions, less materials (e.g. exposed services / and no floor finishes). Where an embodied carbon "cap or quota" is established, then these design strategies become an implicit requirement to be able to meet 40-50% reduction targets.	(**0-20%**) – best used at concept stage where the "big" design decisions are resolved (e.g. façade fenestration, structural system strategy, servicing strategy etc.) adopt the lowest carbon system (e.g. prefabricated elements; post-tension structures). Can be used at detailed design, or by the building contractor where there is a design level responsibility.	(**0-15%**) – the phase at which the ability to effectively "benchmark or compare" materials for their embodied carbon content is best served. Look to the lowest carbon supply chain sourcing or carbon neutral products. Ideally, the progression of embodied carbon labelling of individual materials in industry standard units, will provide immense benefit to contractors and sub-contractors to present their information in directly comparable units aligned to the final use of the product (e.g. per square metre of finished wall/floor/ceiling etc).

The process of setting net zero targets for delivery

1. Select the Building Class Embodied Carbon Quota

Set an embodied carbon not-to-exceed quota in kg CO_2e/m^2 (A1-A5) of (relevant) floor area for the building type

2. Use Modelling to Confirm

Use carbon modelling calculators or tools to confirm design direction has the potential to achieve the quota at concept stage.

3. Apply All Circular Materials

Principles:

- Minimise absolute materials use
- Lowest embodied carbon design
- Highest recycled content
- Low emissions supply chain sources

4. Offset Residual Emissions

Investigate the scope of options to achieve full carbon offset over the ATO defined service life span.

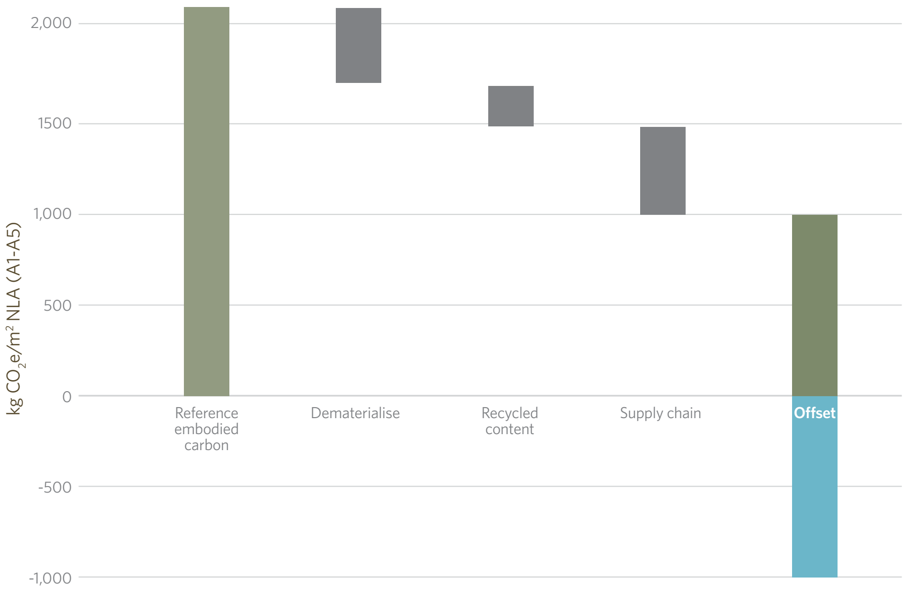
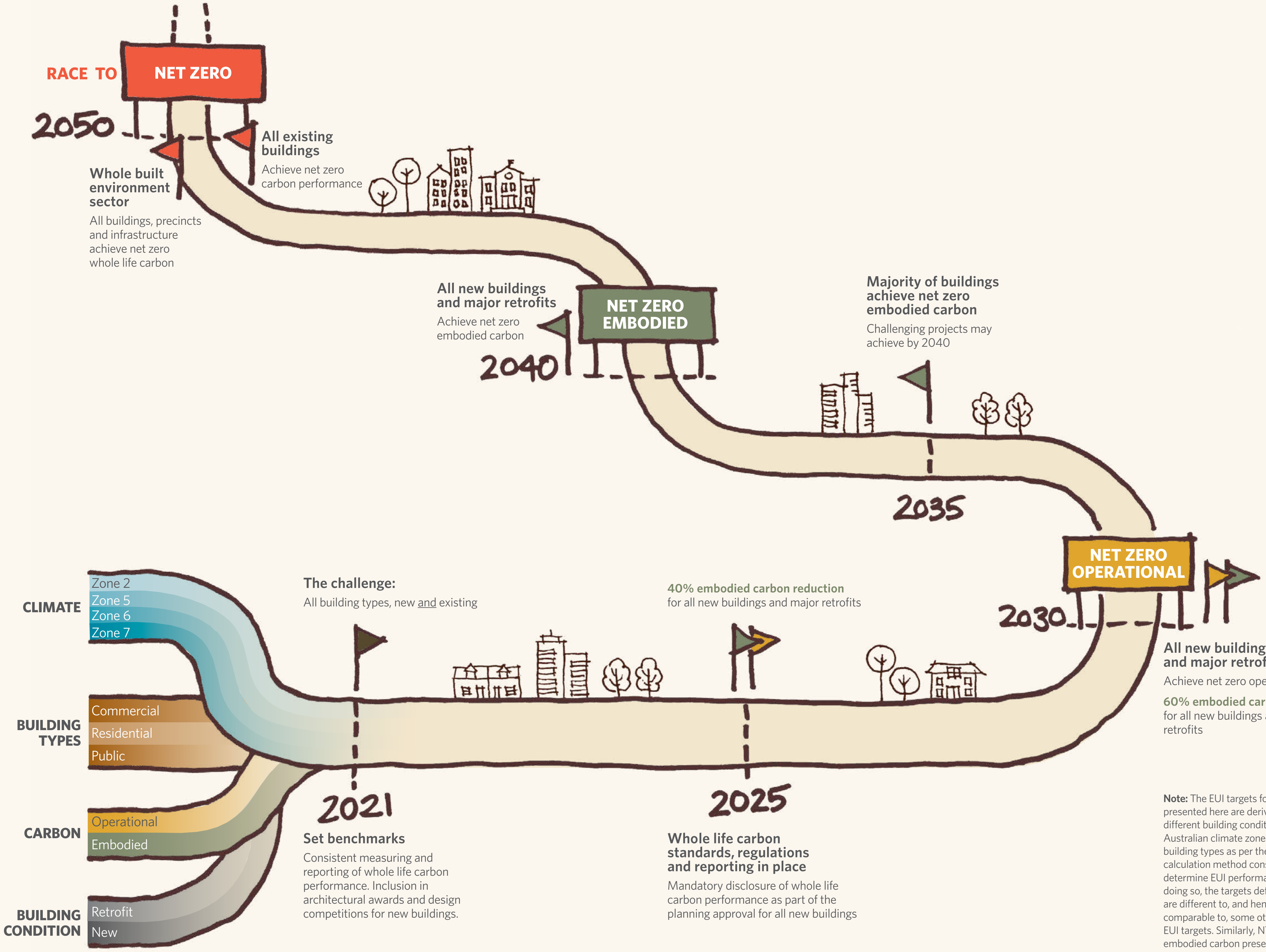


Figure 19: **Achieving net zero embodied carbon**

3.4 Net zero whole life carbon pathway



Note: The EUI targets for operational carbon presented here are derived based on different building conditions, various Australian climate zones and several building types as per the NCC. The calculation method considers GFA to determine EUI performance targets. In doing so, the targets defined in this guide are different to, and hence not directly comparable to, some other local and global EUI targets. Similarly, NTE targets for embodied carbon presented here are higher than those typically presented in the literature and other benchmarks. This is due to the completeness of the materials included in the analysis in this guide, and the Hybrid/Hybrid method used (for example, including preliminaries, external services, etc). As such, care should be taken when using these benchmarks, to ensure any comparisons utilise the same comprehensive methods and boundaries.

Operational carbon performance targets for new buildings and major renovations

		2030 minimum performance targets (EUI GFA*)	Min. performance targets (EUI NFA* if applicable)	Performance equivalent to^	Operational carbon target
Class 1: Detached house	National	11-36		NatHERS# or Green Star Homes equivalent with 100% Green Power	NET ZERO with 100% Green Power
	CZ 2	11-35			
	CZ 5	11-35			
	CZ 6	11-36			
	CZ 7	11-37			
Class 1: Semi-detached house	National	11-34			
	CZ 2	10-34			
	CZ 5	10-33			
	CZ 6	11-35			
	CZ 7	11-36			
Class 2: Residential apartment	National	29-55	23-44	NatHERS#, NABERS or Green Star Buildings rating with 100% Green Power	
	CZ 2	29-54	23-43		
	CZ 5	29-54	23-43		
	CZ 6	29-56	23-44		
	CZ 7	30-57	24-45		
Class 3: Hotel	National	71-77		NABERS or Green Star Buildings with 100% Green Power	
	CZ 2	76-81			
	CZ 5	73-77			
	CZ 6	69-74			
	CZ 7	69-78			
Class 5: Office	National	63-67	55-58		
	CZ 2	69-77	60-67		
	CZ 5	66-72	57-63		
	CZ 6	56-68	49-59		
	CZ 7	57-68	49-59		
Class 6: Retail	National	70-181	49-126		
	CZ 2	75-195	52-136		
	CZ 5	69-179	48-125		
	CZ 6	67-173	46-121		
	CZ 7	68-175	47-122		
Class 9a: Hospital	National	68-115		Green Star Buildings rating with 100% Green Power	
	CZ 2	67-113			
	CZ 5	63-108			
	CZ 6	72-121			
	CZ 7	71-119			
Class 9b: Educational building	National	29-36			
	CZ 2	33-43			
	CZ 5	29-31			
	CZ 6	20-30			
	CZ 7	32-40			
Class 9b: Public assembly building	National	44-48			
	CZ 2	44-48			
	CZ 5	44-48			
	CZ 6	44-48			
	CZ 7	44-48			

Embodied carbon performance targets for new buildings and major renovations

Class	Building type	Embodied Carbon NTE* Minimum Performance Targets 2021	2025^	2030^	2040^
1	Residential (Timber/Brick Veneer)	1,270	762	610	Net zero with eligible offsets
1	Residential (Concrete/Brick)	1,464	878	703	
2	Multi-Residential (Low/Mid Rise <25m)	1,975	1,185	948	
2	Multi-Residential (High Rise >25m)	3,354	2,012	1,610	
5	Office (A Grade)	3,365	2,019	1,615	
5	Office Fitout	1,880	1,128	902	
6	Retail (Regional/Sub-Regional)	3,264	1,958	1,567	
6	Food Retail Fitout	882	529	423	
6	Non-food Retail Fitout	562	337	270	
7	Carpark (Basement/Deck)	2,012	1,207	966	

* Not-to-Exceed targets in $kgCO_2e/m^2$ NLA (A1-A5) represent maximum allowable embodied carbon

^ Mandatory reporting

4

CONCLUDING REMARK

This guide outlines benchmarks for operational and embodied carbon emissions, with the aim of moving Australia to a net zero whole life carbon built environment. It uses currently available data and best practice methods to determine current performance and climate emergency targets. However, as more fine-tuned methods and updated building performance data emerge, and regional energy systems change in the coming years, there will be a need to revise assumptions and update the figures within. As such, the authors aim to revise these benchmarks every three years, to ensure building professionals are comparing performance against the best possible data.

This guide is an extract of a much larger book: *Delivering on the Climate Emergency: Towards a Net Zero Carbon Built Environment*. The book presents a detailed review of the global state of play of the research and practice of the net zero carbon built environment. It describes detailed methodology and presents a broad range of strategies, assessment tools and techniques, and best practice in terms of exemplar low carbon building and precinct designs, energy technologies, and circular economy projects. It is expected to be suitable for international audiences including architects, designers, consultants, developers, owners, academic professions, as well as undergraduate and postgraduate students who as the future practitioners and educators may be interested in exploring the subject of net zero carbon built environment in further detail.

APPENDICES

The contents of this guide, including the climate emergency performance targets, strategies, and implementation and reporting templates presented on the following pages, could all be useful during a practical conversation between the client and the designers on how to navigate to net zero, and by when. Such a conversation would ideally start with the project brief and involve discussions about the levels of onsite efficiency to be achieved, the optimisation of onsite renewable energy generation (and storage as appropriate), and how best to balance the remaining carbon emissions with either offsite renewable energy or, as a last resort, eligible carbon offsets for a net zero whole life carbon outcome. This could include considerations of any budget implications, time factor, or any other project specific constraints and opportunities for net zero. Such a conversation should lead to a commitment agreement for net zero performance, which can anchor the conversations, and drive decisions, across the project stages from concept design through to construction completion, as well as post-occupancy operational life and beyond.

A.1 Implementation and reporting

Implementation checklist

		Operational Carbon B6	Embodied Carbon A1-A5
Internal Commitment			
Partners and employees commitment and education	**Commitment**		
	Inform/confirm that the practice is involved in the Race to Net Zero Carbon		
	Develop and implement a design philosophy centring around carbon efficient building development		
	Acquire the Race to Net Zero Carbon guide		
	Education		
	Require all employees to become educated in carbon efficient buildings		
	Require all employees to become educated in renewable energy generation		
	Organise events and discussions on the application of Race to Net Zero Carbon guide		
External Commitment			
Client, stakeholders and consultants communication and management	**Client and stakeholders**		
	Inform/confirm that the practice is involved in the Race to Net Zero Carbon		
	Discuss the benefits of committing to the race		
	Explain the importance of reducing carbon emissions in the building sector in Australia as a national goal		
	Engage clients in discussions regarding carbon efficient buildings		
	Discuss how carbon efficient building design can be cost-effective		
	Establish a portfolio that highlights the practice's carbon efficient projects		
	Consultants		
	Engage consultants who are committed to the Race to Net Zero Carbon		
	Involve consultants in the project development at an early design stage		
	Approach projects with a focus on energy efficient design		
	Approach projects with a focus on energy generation from renewable sources		
Implementation			
Project development and verification to meet the checkpoints and targets	**Setting targets**		
	Familiarise the employees with the current benchmarks		
	Familiarise the employees with the Australian Climate Emergency performance targets		
	Familiarise the employees with the energy generation targets		
	Calculate energy use of projects using tools with the help of consultants		
	Complete the Race to Net Zero Carbon reporting		
	Compare your project`s performance against benchmarks and targets		
	Calculate carbon reduction required to meet the targets		
	Adopting carbon efficient strategies		
	Familiarise the employees with the carbon efficient strategies		
	Determine suitable carbon efficient strategies applicable to the project		
	Calculate carbon reduction achievable through the suitable energy efficient strategies		
	Procuring renewable energy		
	Familiarise the employees with renewable energy procurement		
	Determine suitable renewable energy sources applicable to the project		
	Calculate energy generation required through the suitable renewable energy sources		
Data Disclosure			
Metering and data disclosure of energy consumption, carbon emission and carbon offset	**Metering**		
	Submeter renewables for energy generation		
	Submeter energy consumption		
	Continuously monitor with a smart meter		
	Consider monitoring internal conditions		
	Include a data logger alongside the smart meter to make data sharing possible		
	Data disclosure		
	Disclose annual building energy consumption and generation		
	Aggregate average operational reporting e.g. by post code for anonymity or upstream meters		
	Be open to share the data		

Reporting template

(example)

Operational Carbon				
As Designed	Unit	Result	CE Target*	Accomplished Yes/No^
Energy use - Whole Building (base + tenant end-use)	kWh/m²/yr	49	50	Yes
Green Star performance credit: Energy	point	22	22	Yes
As Built	Unit	Result	CE Target*	Accomplished Yes/No^
Energy use - Whole Building (base + tenant end-use)	kWh/m²/yr	55	65	Yes
Green Star performance credit: Energy	points	22	22	Yes
NatHERS Rating	star	10		
BASIX Rating	-	70		
Energy Efficient Systems	Unit	Reference	As Designed	As Built
HVAC	kWh	98,958		
Equipment	kWh	68,937		
Lighting appliances	kWh	60,349		
Other systems	kWh	60,349		
Energy Generation		Amount	As Designed (%)	As Built (%)
On-site energy generation	kWh	112,741		
Off-site energy generation	kWh	100,246		
Green power	kWh			
Carbon Offset	Unit	Result	CE Target*	Accomplished Yes/No^
Total carbon emissions	kg CO_2e	+ 230,154	Net zero	Yes
Carbon offset	kg CO_2e	- 212,987		
Overall emissions to be achieved		17,167		

Embodied Carbon				
As Designed	Unit	Result	CE Target*	Accomplished Yes/No^
Embodied Carbon Intensity Absolute	kg CO_2e/m²	2000	2019	Yes
Embodied Carbon Intensity Annual	kgCO_2e/m²/yr	50	<200	Yes
As Built	Unit	Result	CE Target*	Accomplished Yes/No^
Embodied Carbon Intensity Absolute	kg CO_2e/m²	2000	Meets or exceeds design	Yes
Contributors	Unit	Result	Key Strategies	
Foundations	kg CO_2e/m²	100	Geopolymer	
Super-Structure	kg CO_2e/m²	200	100% recycled steel	
Envelope (Windows and Walls)	kg CO_2e/m²	400	Low carbon glass	
Internal Walls	kg CO_2e/m²	200	Hebel	
Internal Finishes	kg CO_2e/m²	100	Recycled content	
Services	kg CO_2e/m²	500	Low carbon steel/ reclaimed copper	
External Site Works and Services	kg CO_2e/m²	100	Reduced time for prefab	
Preliminaries	kg CO_2e/m²	400		
Carbon Offset	Unit	Result	CE Target*	Accomplished Yes/No^
Total carbon emissions	kg CO_2e	+ (report value)	Net zero	Yes
Carbon offset	kg CO_2e	- (report value)		
Overall emissions to be achieved	kg CO_2e	0		

Carbon Status	Operational carbon status					Embodied carbon status				
Status of carbon offsetting Yes/No	Yes					No				
Emission Reduction Plan	% of achievement	Remaining target	Operational carbon plan	Year due	Stages of the plan	% of achievement	Remaining target	Embodied carbon plan	Year due	Stages of the plan
Emission reduction plan to achieve net zero status	92%	8%	On track	2023	1 stage	50%	50%	On track	2030	2 stages
Net Zero Plan	Stages	Required carbon offset	Operational carbon plan	Strategy	Year due	Stages	Required carbon offset	Embodied carbon plan	Strategy	Year due
Plan to achive net zero carbon	Stage 1	8% or 17,167 kg CO2e	Energy efficiency	Variable thermostat controls for HVAC upgrade	2023	Stage 1	25%	Envelope mitigation	Upgrade to low carbon materials	2024
						Stage 2	25%	Services	Use reclaimed or recycled materials	2030

* Please enter the CE performance targets from Table 3 for operational carbon and from Table 5 for embodied carbon.

^ Please report the accomplishment of your project. If the result is equal to or less than the CE Target, report 'Yes' as accomplished. If the result is more than the CE Target, report 'No' as on track. Everything reported as a 'No' is suggested to be listed in the 'Net Zero Plan' with a plan to achieve a net zero status.

A.2 Comparing and combining operational and embodied data from this guide

This guide sets out benchmarks and targets for operational energy and embodied carbon using different metrics (kWh/m²GFA/annum and kgCO_2e/m²NLA). This is because we used different methodologies to determine these.

However, some practitioners may wish to compare or combine the data for operational and embodied performance in their building. To do so, two steps are needed to convert the operational energy data to comparable carbon.

Step 1:
Convert GFA to the floor area defined in the embodied carbon functional unit

Convert or ensure that both operating carbon and embodied carbon values are based on the same functional unit area definition. It is essential to remember that residential and non-residential buildings are measured differently.

For example, an office building may have a NLA that is 83% of the total GFA. In which case if its operational energy was 50kWh/m²GFA/annum, it would also be 60.2kWh/m²NLA/annum.

Step 2:
Convert Electricity to Carbon Dioxide Equivalent (CO_2e)

The energy benchmarks in this guide assume buildings are all electric. Each state in Australia has different emission factors for each kWh of electricity consumed, due to different fuel mixes used. These factors are published by the Australian government in the table below.

In the case mentioned before, an office building with operating energy of 60.2kWh/m²NLA/annum, would be responsible for carbon emissions of 60.2 x 0.81 = 48.76kgCO_2e/m²NLA in NSW and ACT, but 60.2 x 0.17 = 10.23m² kgCO_2e/ NLA in Tasmania.

***Example:** An office building in Sydney*

An A-grade CBD office building in Sydney is designed to perform at the benchmark level for both operational and embodied emissions in 2030. Its NLA is 80% of the GFA.

Operational = 66kWh/m²GFA/annum (CZ5, 2030 target)

Embodied = 1,615 kgCO_2e/m²NLA

66 x (1/0.8) = 82.5kWh/m²NLA/annum

82.5 x 0.81 = 66.8 kgCO_2e/m²NLA

In this instance, the building's embodied carbon (A1 – A5) is equivalent to 24.2 years of operating emissions (at a 2020 baseline).

Limitations:

The method outlined here for comparing operational carbon with embodied carbon is useful for 2020 only (one year). This is because as we decarbonise the grid the emission factors will change.

Therefore, while 66kWh = 53kgCO_2e in 2020 in NSW, it might be 45kgCO_2e in 2025 and 30kgCO_2e in 2030 – even where EUI stays the same. With a fully decarbonised grid 66kWh would equal ≈ 0kgCO_2e in 2050.

2020 indirect (scope 2) emission factors for purchased electricity

State or territory	Emission factor kg CO_2e/kWh
New South Wales and Australian Capital Territory	0.81
Victoria	0.98
Queensland	0.81
South Australia	0.43
South West Interconnected System (SWIS) in Western Australia	0.68
North West Interconnected System (SWIS) in Western Australia	0.58
Darwin Katherine Interconnected System (DKIS) in Northern Territory	0.53
Tasmania	0.17
Northern Territory	0.62

Source: Department of Industry, Science, Energy and Resources[58]

A.3 Further reading

We hope the data and advice presented in this guide will help built environment professionals establish appropriate benchmarks and targets for their individual building projects and assist in achieving significant reductions in carbon emissions for delivering a net zero carbon built environment. If you found this guide useful, please share it with others in the industry.

If you are looking for further information, browse these reading suggestions.

- **Book:**

  Delivering on the Climate Emergency: Towards a Net Zero Carbon Built Environment

- **CRC for Low Carbon Living guides:**

  Each Low Carbon guide summarises best practice in various phases of the building life cycle—construction, retrofit, operation—for a range of building types in the residential and commercial sectors and at the level of precincts. The series includes:

  Guide to Low Carbon Residential Buildings – New Build

  Options for homeowners, builders and designers during the planning and construction of new homes.

  Guide to Low Carbon Residential Buildings – Retrofit

  Retrofit solutions for existing homes, tailored for homeowners and their contractors.

  Guide to Low Carbon Households

  Advice to homeowners and renters on operating households using low carbon living approaches.

  Guide to Low Carbon Commercial Buildings – New Build

  The design and construction of low carbon commercial buildings.

  Guide to Low Carbon Commercial Buildings – Retrofit

  Methods for retrofitting commercial buildings to improve performance while reducing energy and carbon use.

  Guide to Low Carbon Precincts

  Frameworks and options to assist councils and developers with strategic planning decisions when implementing low-carbon neighbourhoods.

  Further guides cover Landscape, Urban Cooling, Value-chain and other topics. For further information go to lowcarbonlivingcrc.com.au.

REFERENCES

1. Standards Australia, *Gross Floor Area*. National Dictionary of Building & Plumbing Terms. 2020. Available from: https://www.constructiondictionary.com.au/term/gross-floor-area [Accessed 18 July 2021].

2. Standards Australia, *Net Lettable Area*. National Dictionary of Building & Plumbing Terms. 2020. Available from: https://www.constructiondictionary.com.au/term/net-lettable-area [Accessed 18 July 2021].

3. International Energy Agency. *Net Zero by 2050: A Roadmap for the Global Energy Sector*. 2021. Available from: https://www.iea.org/reports/net-zero-by-2050

4. Royan Danish Academy and International Union of Architects (UIA), *An Architecture Guide to the UN 17 Sustainable Development Goals*. 2021. Available from: https://uia2023cph.org/the-guides [Accessed 15 June 2021].

5. OxfordLanguages, *Word of the Year 2019*. 2021. Available from: https://languages.oup.com/word-of-the-year/2019/ [Accessed 12 March 2021].

6. Climate Council, *140-Year heat map shows clear trend in global temperature change*. 2020. Available from: https://www.climatecouncil.org.au/resources/140-year-heat-map-shows-clear-trend-global-temperature-change/ [Accessed 18 June 2021].

7. Hausfather, Z., *State of the climate: 2020 ties as warmest year on record*. State of the Climate. 2021. Available from: https://www.carbonbrief.org/state-of-the-climate-2020-ties-as-warmest-year-on-record [Accessed 20 April 2021].

8. Ritchie, H. and Roser, M., F*uture Greenhouse Gas Emissions*. 2020. Available from: https://ourworldindata.org/future-emissions#future-greenhouse-gas-emissions-scenarios [Accessed 21 March 2021].

9. Bruyère, C., Buckley, B., Prein, A., Holland, G., Leplastrier, M., Henderson, D., Chan, P., Done, J., and Dyer, A. *Severe weather in a changing climate*. 2020. IAG and National Centre for Atmospheric Research. Available from: https://www.iag.com.au/sites/default/files/Documents/Climate%20action/Severe-weather-in-a-changing-climate-2nd-Edition.pdf

10. Climate Action Tracker, Temperature. 2021. Available from: https://climateactiontracker.org/global/temperatures/ [Accessed 23 May 2022]

11. Australian Academy of Science. *The Risks to Australia of a 3°C Warmer World*. 2021. Available from: https://www.science.org.au/supporting-science/science-policy-and-analysis/reports-and-publications/risks-australia-three-degrees-c-warmer-world

12. Steffen, W. and Bradshaw, S. Hitting Home: *The Compounding Costs of Climate Inaction*. 2021. Climate Council. Available from: https://www.climatecouncil.org.au/wp-content/uploads/2021/01/hitting-home-report-V7-210122.pdf

13. AIA-CLF. *Embodied Carbon Toolkit for Architects*. 2022. Available from: https://carbonleadershipforum.org/toolkit-1-introduction/ [Accessed 20 May 2022]

14. ClimateWorks Australia. *Decarbonisation Futures: Solutions, actions and benchmarks for a net zero emissions Australia*. 2020. Melbourne. Available from: https://www.climateworksaustralia.org/wp-content/uploads/2020/04/Decarbonisation-Futures-March-2020-full-report-.pdf

15. ASBEC and ClimateWorks Australia. *Built to Perform: An industry led pathway to a zero carbon ready building code. Building Code Energy Performance Trajectory Project – Final Report*. 2018. ClimateWorks Australia: Melbourne. Available from: http://www.asbec.asn.au/research-items/built-perform/

16. Merriam-Webster, *Life cycle*. 2021. Available from: https://www.merriam-webster.com/dictionary/life%20cycle [Accessed 15 October 2021].

17. RICS. *Whole life carbon assessment for the built environment*. RICS professional standards, UK. 2017. London. Available from: https://www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf

18. London Energy Transformation Initiative. *LETI Embodied Carbon Primer: Supplementary guidance to the Climate Emergency Design Guide*. 2020. Available from: https://www.leti.london/ecp

19. Simonen, K., Rodriguez, B., McDade, E., and Strain, L. *Embodied Carbon Benchmark Study: LCA for Low Carbon Construction - Part One*. 2017. The Carbon Leadership Forum. Available from: https://carbonleadershipforum.org/wp-content/uploads/2017/02/CLF-Embodied-Carbon-Benchmark-Study.pdf

20. ASBEC. *Low Carbon, High Performance: How buildings can make a major contribution to Australia's emissions and productivity goals*. 2016. Available from: http://www.climateworksaustralia.org/sites/default/files/documents/publications/full_report_-_low_carbon_high_performance_-_final_-_20160511.pdf

21. World Green Building Council. *Advancing Net Zero Status Report 2020*. 2020. Available from: https://www.worldgbc.org/advancing-net-zero-status-report-2020

22. ASBEC. *Ratings Snapshot: Built environment sustainability frameworks commonly used in Australia*. 2021. Available from: https://www.asbec.asn.au/wordpress/wp-content/uploads/2021/08/210727-ASBEC_RatingsSnapshot_website-upload.pdf

23. GBCA. *Climate Positive Buildings & our Net Zero Ambition: Guidance for Green Star on the use of offsets and renewables*. 2021. Available from: https://gbca-web.s3.amazonaws.com/media/documents/climate-positive-buildings-net-zero-ambitions_Z3pcK5R.pdf

24. World Green Building Council, *The Net Zero Carbon Buildings Commitment – FAQs*. 2021. Available from: https://www.worldgbc.org/thecommitment [Accessed 18 June 2021].

25. London Energy Transformation Initiative. *LETI Climate Emergency Design Guide: How new buildings can meet UK climate change targets*. 2020. Available from: https://www.leti.london/cedg

26. Energy & Climate Intelligence Unit, *Net Zero Tracker*. 2021. Available from: https://eciu.net/netzerotracker [Accessed 18 July 2021].

27. World Green Building Council. *Bringing Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon*. 2019. Available from: https://worldgbc.org/article/bringing-embodied-carbon-upfront/

28. Royal Institute of British Architects. *2030 Climate Challenge Version 2 (2021)*. 2021. London. Available from: https://www.architecture.com/-/media/files/climate-action/riba-2030-climate-challenge.pdf

29. London Energy Transformation Initiative. *Embodied Carbon Target Alignment*. 2021. Available from: https://b80d7a04-1c28-45e2-b904-e0715cface93.filesusr.com/ugd/252d09_89cf50315c884fa796fdf07d1428b2e6.pdf

30. Architecture 2030, *2030 Challenges*. n.d. Available from: https://architecture2030.org/2030_challenges/ [Accessed 19 Jun 2021].

31. The American Institute of Architects, *The 2030 Commitment: Are you up for the challenge?* 2021. Available from: https://www.aia.org/resources/202041-the-2030-commitment [Accessed 19 July 2021].

32. Passive House Plus, *Denmark sets out phased embodied carbon targets for buildings News desk*. 2021. Available from: https://passivehouseplus.co.uk/news/general/denmark-sets-out-phased-embodied-carbon-targets-for-buildings [Accessed 11 June 2021].

33. ClimateWorks Australia. State and territory climate action: Leading policies and programs in Australia. 2021. Available from: https://www.climateworksaustralia.org/wp-content/uploads/2021/10/CWA_State-and-territory-climate-action_October-2021.pdf

34. ClimateWorks Australia. *Net zero momentum tracker – local government report.* 2020. Available from: https://www.climateworksaustralia.org/resource/net-zero-momentum-tracker-local-government-report/

35. WSP, Common Capital, WT Partnership, and Elton Consulting. P*lanning for net zero energy buildings: Performance standards to achieve high-performing net zero energy buildings in Greater Sydney*. 2021. City of Sydney. Available from: https://www.cityofsydney.nsw.gov.au/surveys-case-studies-reports/planning-for-net-zero-energy-buildings

36. Dutch Green Building Council, *Paris Proof*. 2021. Available from: https://www.dgbc.nl/themas/paris-proof [Accessed 19 July 2021].

37. UK Green Building Council. *Energy performance targets for net zero carbon offices: Technical report and summary of consultation responses*. 2020. London. Available from: https://www.ukgbc.org/ukgbc-work/net-zero-carbon-energy-performance-targets-for-offices/

38. Bannister, P., Moffitt, S., Zhang, H., Johnston, D., Shen, D., Robinson, D., Cooper, P., Ma, Z., Ledo, L., and Green, L. *Building Code Energy Performance Trajectory – Final Technical Report*. 2018. CRC for Low Carbon Living. Available from: www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/sp0016_trajectory_project_final_tech_report.pdf

39. Council of Australian Governments. *Baseline Energy Consumption and Greenhouse Gas Emissions In Commercial Buildings in Australia – Part 1 – Report.* 2012. Department of Climate Change and Energy Efficiency. Available from: https://www.energy.gov.au/publications/baseline-energy-consumption-and-greenhouse-gas-emissions-commercial-buildings-australia

40. Strategy Policy Research. *Emissions and energy savings from potential changes to National Construction Code energy performance requirements – the Code Calculator*. 2017. Commonwealth of Australia. Available from: https://www.energy.gov.au/publications/building-code-calculator

41. Riedy, C., Lederwasch, A., and Ison, N. *Defining Zero Emission Buildings – Review and Recommenations: Final Report*. 2011. ASBEC. Available from: https://www.asbec.asn.au/research-items/zero-emissions-residential-defining-zero-emission-buildings-review-and-recommendations-report/

42. BuiltBetter, *Low carbon guides*. 2017. Available from: https://builtbetter.org/lowcarbonguides [Accessed 19 July 2021].

43. Augros, R., Dixon, I., Oldfield, P., Partridge, L., Slee, B., and Vasilakopoulou, K. *Guide to Low Carbon Commercial Buildings - New Build*. 2019. CRC for Low Carbon Living. Available from: https://www.unsworks.unsw.edu.au/primo-explore/fulldisplay/unsworks_modsunsworks_64804/UNSWORKS

44. Drosou, V., Giama, E., Oxizidis, S., Papadopoulos, A., and Santamouris, M. *Guide to Low Carbon Commercial Buildings - Retrofit*. 2018. CRC for Low Carbon Living. Available from: http://www.lowcarbonlivingcrc.com.au/resources/crc-publications/guide-low-carbon-commercial-buildings-%E2%80%93-retrofit

45. Beyond Zero Emissions. *Zero Carbon Australia: Buildings Plan*. 2013. Emissions, B.Z.: Fitzroy, Victoria. Available from: http://media.bze.org.au/bp/bze_buildings_plan.pdf

46. Byrne, J., Taylor, M., Ambrose, M., Berry, S., and Sproul, A. *Guide to Low Carbon Residential Buildings – New Build. 2018*. CRC for Low Carbon Living. Available from: http://www.lowcarbonlivingcrc.com.au/resources/-crc-publications/guide-low-carbon-residential-buildings-%E2%80%93-new-build

47. Whitehouse, M., Osmond, P., Daly, D., Kokogiannakis, G., Jones, D., Picard–Bromilow, A., and Cooper, P. *Guide to Low Carbon Residential Buildings – Retrofit*. 2018. CRC for Low Carbon Living. Available from: http://www.lowcarbonlivingcrc.com.au/resources/crc-publications/guide-low-carbon-residential-buildings-%E2%80%93-retrofit

48. The Footprint Company, *The Footprint Calculator*. 2020. Available from: https://footprintcompany.com/the-lca-calculators/ [Accessed 20 July 2021].

49. Property Council of Australia, *A Guide to Office Building Quality – 3rd Edition*. 2019. Available from: https://research.propertycouncil.com.au/research-and-data/a-guide-to-office-building-quality [Accessed 20 July 2021].

50. Carre, A. *A comparative life cycle assessment of alternative constructions of a typical Australian house design*. Market Access and Development, Project number: PNA147-0809. 2011. Available from: http://www.fwpa.com.au/sites/default/files/PNA147-0809_Research_Report_Comparative-LCA_0.pdf http://www.fwpa.com.au/sites/default/files/Addendum_Construction_Type_Costing.pdf

51. GBCA and thinkstep-anz. *Embodied Carbon & Embodied Energy in Australia's Buildings*. 2021. Sydney. Available from: https://gbca-web.s3.amazonaws.com/media/documents/embodied-carbon--embodied-energy-in-australias-buildings-2021-07-22-final-public.pdf

52. Schmidt, M., Crawford, R.H., and Warren-Myers, G., *Quantifying Australia's life cycle greenhouse gas emissions for new homes*. Energy and Buildings, 2020. 224: p. 110287.

53. Röck, M., Saade, M.R.M., Balouktsi, M., Rasmussen, F.N., Birgisdottir, H., Frischknecht, R., Habert, G., Lützkendorf, T., and Passer, A., *Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation*. Applied Energy, 2020. 258: p. 114107.

54. Pasanen, P. and Castro, R., *Carbon Heroes Benchmark Program – whole building embodied carbon profiling*. IOP Conference Series: Earth and Environmental Science, 2019. 323: p. 012028.

55. United Nations Environment Programme. *2021 Global Status Report for Buildings and Construction: Towards a zero-emissions, efficient and resilient buildings and construction sector.* 2021. Nairobi. Available from: https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction

56. Sev, A. and Özgen, *A. Space Efficiency in High-Rise Office Buildings. Middle East Technical University Journal of the Faculty of Architecture*. 26:2. Available from: http://jfa.arch.metu.edu.tr/archive/0258-5316/2009/cilt26/sayi_2/69-89.pdf

57. Crawford, R. et.al, 2022, *The EPiC database: Hybrid Environmental Flow Coefficients for construction materials*. Figure 6, p. 8.

58. Australian Government Department of Industry, Science, Energy and Resources, *National Greenhouse Accounts Factors*. 2020. Commonwealth of Australia. Available from: https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-factors-2020