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# Measuring Embodied Carbon of Buildings: A Review of Methodologies and Benchmarking Towards Net Zero

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**Abstract**. As the world strives towards achieving Net Zero emissions, reducing the carbon footprint of buildings has become a crucial consideration in sustainable development. This research aims to review the current methodologies for measuring embodied carbon of buildings and explore benchmarking strategies towards achieving Net Zero. The literature review covers various methodologies for measuring embodied carbon, including life cycle assessment (LCA) and Whole Building LCA. It also examines the limitations of these methodologies, such as the lack of standardisation and difficulty in measuring embodied carbon for complex building systems. The report highlights the importance of benchmarking embodied carbon, which involves comparing the embodied carbon of a building to a standard industry average. This study also explores the strategies that can be used to reduce embodied carbon in buildings, including material substitution, design optimization, and construction waste reduction. The study emphasizes the need for a holistic approach to reducing embodied carbon based on considering the entire life cycle of building materials and components. It highlights the potential benefits of implementing circular economy principles in reducing embodied carbon, as exemplified by material reuse and recycling. The study concludes that measuring embodied carbon is essential for achieving Net Zero emissions in the building industry. However, there is a need for standardisation and more robust methodologies to measure the embodied carbon of complex building systems. The study recommends the use of benchmarking as a strategy to incentivize the building industry to reduce embodied carbon. The report emphasises the importance of a holistic approach to reducing embodied carbon considering the potential benefits of implementing circular economy principles.

## 1. Introduction

As the importance to address climate change increases, the construction industry in Australia is progressively aiming on further reducing greenhouse gas emissions associated with the built environment. While majority of the research and funding has been placed on operational energy efficiency and renewable energy use in buildings, the environmental impact of construction materials and its manufacturing, known as embodied carbon, has gained importance. Measuring embodied carbon is vital for understanding the total emissions associated with a building's lifecycle and for benchmarking

progress towards net zero emissions goals. This study will provide an overview of methodologies for measuring embodied carbon in buildings, highlights the importance of benchmarking and investigates the path towards achieving net zero embodied carbon in Australia. Furthermore, this study will detail the best practices that demonstrate successful efforts in reducing embodied carbon in building projects. With the research in this study, the aim will be to identify possible strategies that will be effective solutions that can be applied to future projects to reduce the embodied carbon.

The choice of building materials, concrete, steel, and aluminium have a high embodied carbon due to their production processes while materials such as timber and bamboo have a low embodied carbon due to their renewable and sustainable nature. Another factor that affects the embodied carbon of buildings is transportation. The distance between the manufacturing site of the building materials and the construction site of a building can significantly impact the embodied carbon of a building. Transportation also contributes to the carbon emissions associated with the building materials. In addition to materials and transportation, building design also plays a critical factor in determining the embodied carbon of a building. The design of a building can impacts the materials used, the construction process, and the energy efficiency of the building, which all affects the embodied carbon of the building. In addition, another major issue arises owing to the lack of standardised methodologies, tools, and data for measuring and reducing the embodied carbon of buildings.

Currently, there is no standardised methodology or tool for measuring embodied carbon in buildings. This lack of standardisation makes it difficult to compare embodied carbon across different buildings, which makes it challenging to set targets and track progress towards reducing embodied carbon. Even as the importance of measuring embodied carbon in building becomes increasingly apparent as governments, organisations and individuals recognise the urgency of reducing greenhouse gas emissions, the lack of standardization constitutes a significant barrier. Another challenge in measuring embodied carbon is the lack of available data. Building products often involve a vast array of suppliers, manufacturers, and contractors, making it challenging to track the origin and production process of building materials. Without accurate data on the embodied carbon of a building materials, accurate measurement of the embodied carbon of a building becomes challenging. Additionally, measuring embodied carbon is often not a priority for building designers and constructors, as operational carbon emissions are often viewed as the more critical issue. Such lack of awareness and prioritisation when it comes to embodied carbon means that it often goes unmeasured and unreported.

In Australia the problem faced with embodied carbon emissions is that is often overlooked, according to the Australian Bureau of statistics, the construction industry in Australia accounts for approx. 23% of Australia's greenhouse gas emissions in 2018-2019, of that 11% are produced by the embodied carbon of building materials, which is equivalent to approx. 49 million tonnes of carbon dioxide per year. Additionally, Australia has a limited awareness for embodied carbon and understanding of its impacts therefore, it is frequently overlooked in the construction industry as the federal and state governments do not have any legislation regarding the amount of embodied carbon allowed / used on a construction project. The high level of embodied carbon derives from the country's high reliance on fossil fuels for energy production. The increase in awareness and understanding of the topic will significantly assist with lowering not only the embodied carbon of building but dramatically reduce the greenhouse gas emissions to reach their climate targets and mitigate the impacts of climate change.

Therefore, the problem this research seeks to address pertains to the challenges surrounding measurement and reduction of embodied carbon in buildings. In addressing this problem, the study reviews the current methodologies for measuring embodied carbon of buildings and explore benchmarking strategies towards achieving net zero. The study aims to identify the limitations of existing methodologies and explore the potential of benchmarking as a strategy to incentivise the building industry to reduce embodied carbon. The study also aims to explore the strategies that can be used to reduce embodied carbon in buildings, such as material substitution, design optimisation, and construction waste reduction. The study will highlight the need for a holistic approach to reducing embodied carbon and the potential benefits of implementing circular economy principles. The goal of

this study is to provide insights into the best practices for measuring embodied carbon and strategies for reducing it, thereby contributing towards achieving net zero emissions in the building industry.

## 2. Literature Review

Buildings are responsible for a significant portion of global greenhouse gas emissions and reducing their carbon footprint has become a crucial aspect of sustainable development. In recent years, there has been an increasing focus on embodied carbon, which refers to the carbon emissions released during the extraction, processing, manufacturing, and transportation of building materials and components. This literature review aims to provide an overview of the current state of knowledge on embodied carbon in buildings, including the methodologies used to measure it, the factors influencing it, and strategies for reducing it.

### *2.1 Methodologies for Measuring Embodied Carbon*

Measuring embodied carbon is an important step in understanding the carbon footprint of a product or material, and it is increasingly being incorporated into building design and construction. There are several methodologies for measuring embodied carbon, including:

#### *2.1.1 Life* Cycle Assessment (LCA)

LCA is a widely used methodology for measuring the environmental impact of a product or material over its entire life cycle. It considers all the inputs and outputs associated with the production, use and disposal of the product, including energy consumption, emissions, and waste generation (De Wolf, Pomponi, & Moncaster, 2017).

#### *2.1.2 Carbon Foot printing*

Carbon foot printing is a methodology that calculates the carbon emissions associated with a product or material. It typically focuses on the operational emissions associated with the use of a product but can also include embodied carbon emissions (De Wolf, Pomponi, & Moncaster, 2017).

#### *2.1.3 Whole Building Life Cycle Assessment (WBLCA)*

WBLCA is a methodology that evaluates the environmental impact of a building over its entire life cycle, including the embodied carbon emissions associated with the materials used in construction (Futas, Rajput, & Schiano-Phan, 2019).

#### *2.1.4 Environmental Material Assessment (EMA)*

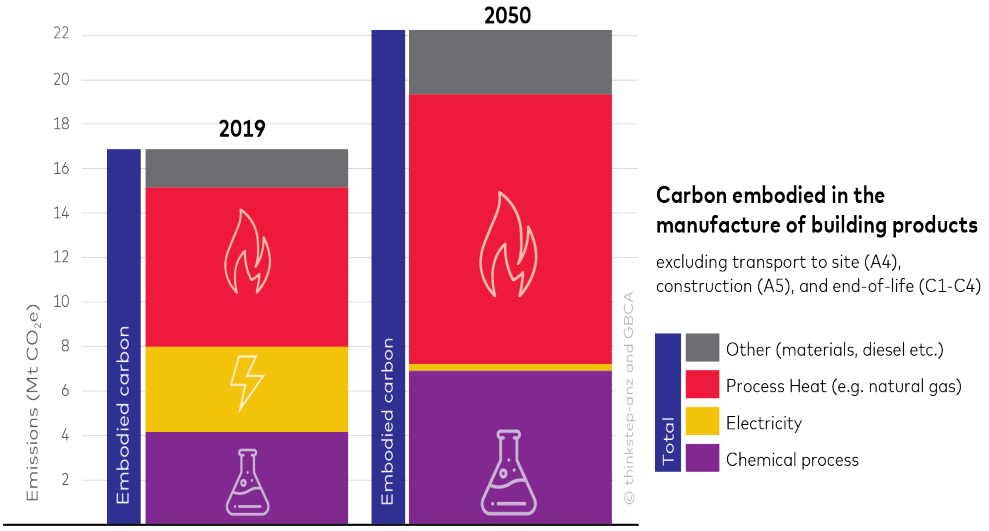
EMA is a methodology that evaluates the environmental impact of a material or product based on its physical and chemical properties. It considers factors such as resource depletion, toxicity, and greenhouse gas emissions.

#### *2.1.5 Cradle-to-Cradle (C2C)*

C2C certification is a methodology that evaluates products based on their environmental and social sustainability. It considers factors such as material health, recyclability, and renewable energy use (Futas, Rajput, & Schiano-Phan, 2019).

### *2.2 Factors Influencing Embodied Carbon in Buildings*

The embodied carbon of a building is influenced by several factors, such as the type of materials used, the location of the building, and the transportation distance of the materials. Figure 1 shows materials with high embodied carbon, such as steel and concrete, contribute significantly to the overall embodied carbon of a building. Lützkendorf and Balouktsi (2022) note that using products that with lower embodied carbon as well as reusing build components can influence embodied carbon, demonstrating the importance of material choices in embodied carbon. The location of a building also affects its embodied carbon, as transportation emissions can be significant (Lützkendorf & Balouktsi, 2022).




*Note*. This graphic was produced by Green Building Council of Australia, summarizing embodied carbon and energy in Australia's buildings. GBCA and thinkstep-anz (2021).

**Figure 1.** Embodied carbon in the manufacturing of building products

*2.3 Strategies for Reducing Embodied Carbon*

Several strategies can be used to reduce embodied carbon in buildings, such as material substitution, design optimisation, and construction waste reduction.

- Material Selection: Material selection is one of the most important factors in reducing embodied carbon in buildings. Material substitution involves using materials with lower embodied carbon, such as timber or recycled materials, instead of high-emitting materials like steel and concrete. Selecting materials that have a lower carbon footprint can significantly reduce the embodied carbon of a building (Lützkendorf & Balouktsi, 2022)
- Design: Design plays a critical role in reducing embodied carbon in buildings. Incorporating design strategies that reduce the need for materials or improve the energy efficiency of that building can help reduce embodied carbon (Pomponi & Moncaster, 2016). Design optimisation involves reducing the overall amount of materials used in a building.
- Construction Techniques: Construction techniques also play an important role in reducing embodied carbon. Construction waste reduction involves reducing the amount of waste generated during construction and diverting it from landfills. Using construction techniques that reduce material waste and emissions can significantly reduce the embodied carbon (Pomponi & Moncaster, 2016).

Measuring embodied carbon in Australia can help reduce the country's carbon emissions in several ways. For Australia to achieve net zero emissions by 2050, the implementation of embodied carbon reduction strategies will enable the low carbon future that it requires. The effort to shift Australia into a low carbon nation will involve various stakeholders such as the government, industry professionals, manufactures and researchers to adopt and make the necessary changes for our countries future.

- Informing policy decisions: Measuring embodied carbon can provide policymakers with valuable data on the carbon emissions associated with different building materials and construction methods. This information can be used to develop policies that incentivize that use of low carbon materials and construction techniques and encourage the adoption of more sustainable building processes.

- Encouraging low carbon innovations: By measuring embodied carbon, Australian architects, builders, and manufacturers can identify opportunities to innovate and develop low carbon alternatives to high emission materials and processes. This can spur the development of new technologies and techniques that can help reduce embodied carbon in the built environment.
- Building Codes & Rating Systems: The integration of embodied carbon considerations into building codes and rating systems such as the National Construction Code (NCC) and Green Star.
- Promoting sustainable building practices: Measuring embodied carbon can also help raise awareness of carbon emissions associated with the built environment, in turn encouraging adoption of more sustainable building practices. By providing data on carbon emissions associated with different materials and processes, Australian building owners and operators can make more informed decisions about how to reduce their carbon footprint.
- Supporting carbon accounting: Measuring embodied carbon can also support carbon accounting efforts by providing more accurate data on the carbon emissions associated with building construction and operations.
- International Collaboration: Leading the global standardisation of embodied carbon into legislation is met by France, Netherlands, Denmark, Finland and Sweden. If Australia was to collaborate with these countries, to focus on embodied carbon reduction and adapt from strategies that have worked from their research. Australia could also engage in initiatives such as Embodied Carbon in Construction (EC3) to learn from global partners on best practices to reduce emissions.
- Meeting carbon reduction targets: Measuring embodied carbon can also help the nation meet its carbon reduction targets by identifying opportunities to reduce emissions in the built environment. By reducing embodied carbon in buildings, Australia can make significant progress towards achieving its emissions reduction goals.
- Material Substitution: Promotion of low carbon and recycled materials on construction projects. To avoid high carbon emissions on projects, the promotion of low carbon materials such as timber would pose as a sustainable alternative to the high carbon materials like steel. The use of recycled materials i.e, bricks could also be used if the property was to have a rendered façade, this in turn allows the client to have their chosen façade with the lower cost of using recycled materials.
- Net Zero Carbon Goals: Net Zero embodied carbon refers to the state where the emissions produced from the building materials and the construction processes are offset or reduced to a level lower or equal to the carbon created.
- Strategies for reduction of Embodied Carbon: For Australia to achieve a net zero embodied carbon, a combination of strategies are required. Some of these strategies include material substitution with lower carbon produced alternatives, optimisation of the design and construction methods to reduce the amount of material used, and sourcing materials with lower carbon footprints. The collaboration between designers, contractors and manufacturers would enable better lower carbon designed buildings leading Australia to reaching its net zero target by 2050.

Overall, measuring embodied carbon in Australia can help the country reduce its carbon emissions by informing policy decisions, encouraging low carbon innovations, and promoting sustainable building practices, supporting carbon accounting efforts, and helping Australia meet its carbon reduction targets. By taking a comprehensive approach to measuring and reducing embodied carbon in the built environment, Australia can move towards a more sustainable future and play a leadership role in global efforts to mitigate climate change.

## 3. Methodologies

Life Cycle Assessment (LCA) is a widely used methodology for measuring the environmental impacts of products and systems, including buildings. LCA measures the environmental impacts of a product or system from cradle to grave, including raw material extraction, manufacturing, transportation, use and end of life disposal. LCA is a comprehensive methodology that considers all environmental impacts, including carbon emissions, water use, energy use and waste generation. LCA can be applied to buildings in various ways, including whole building LCA, which measures the environmental impacts of a building from construction to end of life disposal. Whole building LCA considers all materials used in construction, including the energy required to extract and manufacture the materials, the transportation of the materials to the construction site, and the energy used in the construction process. Environmental Product Declarations (EPDs) are standardised documents that provide information on the environmental impacts of a product of system. EPDs are based on LCA and provide a standardised way to communicate the environmental impacts of a product or system, including carbon emissions, water use, energy use and waste generation. EPDs are particularly useful for building materials as they provide a way for manufacturers to communicate the environmental impacts of their products to architects, engineers, and builders. EPDs allow for the comparison of the environmental impacts of different products to inform material selection decisions.

LCA is a comprehensive methodology that can be time consuming and costly to implement, while EPDs provide information on individual products and not on the while building. A mixed methodology approach that combines the strengths of both LCA and EPDs can provide a more accurate and efficient way to measure embodied carbon in buildings. The approach involves using EPDs to inform the selection of buildings by choosing materials and use of LCA to measure the embodied carbon of the whole building. The use of EPDs to inform material selection decisions can help reduce the embodied carbon of buildings by selecting materials with lower carbon emissions. The use of LCA to measure the embodied carbon of the while building provides a comprehensive way to measure the embodied carbon of the building by applying three main steps (1) material selection, (2) whole building LCA, (3) results verification. The first step is to use EPDs/LCAs to inform material selection decisions. EPDs/LCAs provide information on the environmental impacts of individual products, including carbon emissions. By selecting products with lower carbon emissions, the embodied carbon of the building can be reduced. The second step is to use LCA to measure the embodied carbon of the whole building. Whole building LCA considers all the materials used in construction, including energy required to extract, manufacture and transportation of materials to the construction site. Whole building LCA can also consider the operational energy use of a building, which includes the energy used for heating, cooling, and lighting. After the whole building LCA has been completed, the final step is to verify the results and ensure accuracy (Mohebbi et. al, 2021). Verification can be done through a variety of methods, including peer review, third party verification, and building certification programs.

Building Certification Programs: Building certification programs such as LEED and BREEAM can also be used to verify the embodied carbon of building. These programs provide a standardised way to measure the environmental performance of buildings, including embodied carbon. Building certification programs require a while building LCA to be completed, and the results are verified by independent third parties. Overall, in the absence of a standardised methodology for measuring the embodied carbon of buildings, a mixed methodology approach that combines both LCA and EPDs can provide a more accurate and efficient way to measure the embodied carbon in buildings. The mixed methodology approach involves the use of EPDs to inform material selection decisions and the use of LCA results can be done through peer review, third party verification and building certification programs. By using a mixed methodology approach and verifying the results, the embodied carbon of buildings can be accurately measured and reduced, which can help address the urgent issue of climate change. The first paragraph after a heading is not indented (Bodytext style).

## 4. Discussion

Achieving net zero embodied carbon in buildings requires a comprehensive approach that addresses all stages of the building life cycle, from material extraction and manufacturing to construction, operation, and end of life disposal. Some strategies that can be used to achieve net zero embodied carbon are:

### *4.1 Achieving Net Zero Embodied Carbon*

- Material Selection: Choose low carbon materials, such as timber, bamboo and recycle materials that have a low embodied carbon and can be sourced sustainably. Additionally, prioritize materials with low life cycle impact, such as those that are durable, reusable, and recyclable.
- Carbon Offsetting: offset the carbon emissions associated with building materials by investing in carbon reduction projects, such as renewable energy or reforestation projects. This can help to neutralise the impact of embodied carbon and move towards new zero carbon emissions.
- Building Design: Optimise building design to reduce the overall embodied carbon of a building. This includes designing for energy efficiency, using renewable energy sources, and maximising the use of low carbon materials. With the consideration of embodied carbon during the design phase of a project, it allows designers, architects, and engineers to make environmental decisions.
- Building Operation: Optimise building operation to reduce the energy consumption and minimise the need for carbon intensive maintenance and repair activities. This includes using energy efficient lighting and HVAC systems, as well as implementing smart building technologies.
- Modular & Prefabrication Construction: The use of Modular and Prefabrication construction methods will enable the reduction of construction waste as well as reduce the onsite emissions of the construction while enhancing construction efficiency. Modular builds are able to further reduce embodied carbon as the modular components can be easily disassembled and recycled.
- End-of-Life Disposal: Plan for the end-of-life disposal by designing buildings for disassembly and reuse and implementing recycling and waste reduction strategies. This can minimise the need for new materials and further reduce the overall embodied carbon of a building.
- Life Cycle Assessment: Conducting a life cycle assessment (LCA) of a building to identify the materials and processes with the highest embodied carbon and inform design and construction decisions to reduce the overall embodied carbon of this building.
- Certification Systems: The use of certification systems, such as LEED, BREEAM or Green Star to incentivize the use of low carbon materials and construction techniques and provide a framework for achieving net zero embodied carbon.

### *4.2 Benchmarking Embodied Carbon*

The benchmarking of embodied carbon enables stakeholders to assess the embodied carbon performance in buildings and projects against already established targets and regulations on industry standards. Benchmarking allows for comparative analysis of similar projects, while identifying the best practices and setting goals to reduce the embodied carbon of buildings lower than current industry benchmarks. Benchmarking also enables the tracking of progress and enables stakeholders to make decisions benefiting the project throughout the project's lifecycle. The embodied carbon emissions of products, buildings and infrastructure can be analysed in Australia at this time. With a handful different initiatives and resources in Australia benchmarking embodied carbon. A leading influence in the study of embodied carbon in the nation is the Green Building Council of Australia (GBCA).

The creation of Green Star by the green building council of Australia has provided a benchmarking system for Australian companies for calculating the embodied carbon while evaluating the environmental performance of buildings. Green star aims to promote the sustainable design and operation of buildings. Its research is based on various aspects of sustainability including energy efficiency, material section in buildings, environmental quality and water conservation. Offering a tiered certification system, green star rewards developments on how environmentally sustainable they are. With certification levels ranging from 4 Stars to 6 Stars, A green star certification demonstrates how a

project is actively shrinking its environmental footprint and contributing to a low carbon future, while providing benefits to those awarded with studies showing enhanced occupant health and wellbeing, improved operational efficiency. Stakeholders who choose to prioritize sustainable buildings and are committed to sustainability benefit by attracting more tenants and investors to their project or company.

Examining these carbon intensive industries is essential for identifying key areas where efforts to reduce emissions should be concentrated. A distinct understanding of sector specific carbon footprints is key for governments and industry stakeholders to formulate targeted strategies and aim to mitigate embodied carbon emissions. In the assessment of sustainable construction projects, it is imperative to understand carbon emissions associated with the extraction, production, and transportation of building materials. The scrutiny of the manufacturing industry processes responsible for creating materials is crucial for determining their carbon emission that includes a detailed analysis of the energy sources and an assessment of the emissions generated throughout the manufacturing process. It is important to note the impact of the transportation and logistics of these materials and products and how it effects embodied carbon, a thorough examination of the distance travelled, efficiency of vehicles used, and types of transportation methods can reveal opportunities to minimise carbon emissions and provide cost savings to manufacturers.

### *4.3 Policies and Regulations*

Government initiatives play an essential role in mitigating embodied carbon in Australia, with notable efforts aimed at enhancing regulations and standard within the construction industry. This involves the implementation of stringent building codes specifically addressing the embodied carbon topic, as well as encouraging the adoption of low carbon materials whilst encouraging sustainable construction methods. The government has introduced incentive programs to utilize environmentally friendly practices and technologies to reduce the carbon offset from construction projects. Another way in which the government is focussing on the carbon emissions from construction is the establishment of research and development to explore novel solutions and technologies that have the potential to further reduce embodied carbon in construction processes. The government is actively collaborating with key construction industry stakeholders, including environmental organisations to implement sustainable strategies for minimising embodied carbon and curbing carbon emissions in Australia. The support the government is offering is a step in the right direction to a future of positive change for carbon emissions in the construction industry leading to more a sustainable Australia for future generations to build on.

### *4.4 Building Codes and Standards*

Building codes and standards are vital to Australia's construction industry. The implementation of an embodied carbon framework in Australia's building codes and regulations should be considered and designed to mitigate emissions linked to the production, transportation, and installation of building materials across the industry. The establishment of mandatory practices and guidelines to amend and include sustainable construction practices that actively promote the utilisation of low carbon materials, energy efficient manufacturing processes as well as the integration of renewable energy sources, is a vital consideration that needs to be made by government bodies to allow innovation within the sector. Through these regulatory measures, Australia seeks to attain its climate objectives and progress towards a more sustainable built environment. However, the challenges faced including ensuring widespread compliance, updating standards to align with evolving knowledge and codes across all states and territories requires a staged implementation whilst monitoring the industry capabilities. For these changes to come into effect, the collaboration of government, industries and building professionals are crucial to overcome the challenges faced and drive sustainable solutions within the construction sector. The continuous refinement of building codes are crucial for Australia to effectively address embodied carbon, ultimately allow continuous innovation creating a more environmentally sensible construction.

### *4.5 Material Alternatives*

The benefit of substitution of high carbon materials to low carbon building materials could reduce embodied carbon in Australia dramatically. Sustainable materials exhibit lower carbon footprints in comparison to traditional construction materials, resulting in reduced greenhouse gas emissions during the extraction, production, and transportation to enhance the energy efficiency of a building and overall lowering the carbon emissions throughout a project's lifecycle. The utilisation of incorporating recycled and renewable resources across the industry aid in the effort to reduce embodied carbon in Australia. Recycled materials, such as reclaimed timber or recycled concrete and bricks, allows the construction industry to make substantial progress in minimising its carbon footprint. These materials not only divert waste from landfill sites, but it also demands less energy for production compared to new materials. The integration of renewable resources, such as timber sourced from sustainably managed forests or utilising renewable energy sources in the manufacturing process of materials also displays a large potential to decrease embodied carbon. For Australia to adopt sustainable building practices like the utilisation of recycled and renewable resources needs to be a collaborative effort with industries, governments and building professionals, allowing these initiatives to be enacted across the industry.

### *4.6 Future Research & Development*

Embodied carbon in Australia offers numerous possibilities for further research and development. The ability to enhance the accuracy and reliability of data collection in reference to embodied carbon is crucial for future policy formation and shaping the future of the country. A focus on identifying and addressing obstacles obstructing the reduction of embodied carbon is needed to allow future growth in the industry, these obstacles such as high costs for sustainable materials, limited availability of sustainable materials, and lack of awareness to the public and industry professionals needs to be examined to drive innovative solutions and products better suited to tackle the growing concern over embodied carbon. Understanding these challenges is essential for the development of a framework to overcome the issues and allow industries to transition to a low carbon future. Future research on embodied carbon can explore the potential for technological advancements and innovation in construction processes and materials with the reduction of embodied carbon. The research into future embodied carbon should be a collaboration between stakeholders including governments, industry professionals, researchers, and the public, allowing the promotion of education on the matter and increased awareness, driving common action towards the reduction of embodied carbon in Australia.

## 5. Conclusion

Embodied carbon has emerged as a critical challenge in reducing the carbon footprint of buildings. While several methodologies are available for measuring embodied carbon, lack of standardisation makes it challenging to compare and benchmark buildings. The embodied carbon of a building is influenced by several factors, including the type of materials used and the location of the building. Strategies for reducing embodied carbon include material substitution, design optimisation, and construction waste reduction, as well as the implementation of circular economy principles. A holistic approach to reducing embodied carbon is essential, considering the entire life cycle of building materials and components towards achieving net zero emissions in the building industry.

The adoption of carbon reduction strategies in construction from countries such as the United Kingdom, Sweden, Norway, and Canada displays the benefits of measuring and monitoring embodied carbon in construction projects. The United Kingdom has made significant progress in reducing embodied carbon though initiatives such as the Embodied Carbon Review, which sees the replacement of high embodied carbon materials substituted with lower carbon materials. Sweden known for its strict building regulations as well as commitment to sustainable construction, has led to the innovation of building practices and its use of sustainable materials. Much like Sweden, Norway is led by ambitious climate change goals, with focus on the incorporation of low carbon building strategies and use of sustainable materials for construction. Australia can benefit and adopt from countries like this as well as Canada which has implemented carbon reduction policies for construction companies, this structure

can be incorporated into Australia's building framework legislation and through industry collaboration, Australia would be able to make an impact on the embodied carbon produced by the construction sector.

By addressing the issue of embodied carbon in Australia, the construction industry can contribute considerably to minimising the emissions target set by 2050. For Australia to achieve a low carbon future it requires a collaboration of industries and government to adopt and enforce sustainable practices in both the construction of buildings and manufacturing of building materials. If Australia was to prioritise embodied carbon reduction throughout the industries, the construction industry will be able to dramatically reduce the emissions leading to a more sustainable Australia.

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