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info@warneroo.com

BUILDING AUSTRALIA'S FUTURE: INDUSTRY PERSPECTIVES ON HEMPCRETE PANELS FOR SUSTAINABLE AND AFFORDABLE HOMES

March 2025

Final Draft Report

ENQUIRIES
Dr Julio Mancuso Tradenta
Senior Lecturer
La Trobe University
Victoria 3086

E j.mancusotradenta@latrobe.edu.au

Acknowledgments

The authors would like to express their sincere gratitude to the Warner Research Institute (WRI) who funded this project, members of the WRI Research Committee, Sean Mckay and Clare Johnson for their input and direction provided, and especially to Phil Warner, for his invaluable insights and contributions. We also extend our thanks to Antony Bacic, Veronica Borrett, Monika Doblin, and David Flemming-Munoz, members of the La Trobe Institute of Sustainable Agriculture and Food (LISAF), for their thoughtful comments and expert perspectives throughout the course of this project.

Additionally, we would like to acknowledge the industry experts who participated in the interviews, whose input and perspectives were crucial in shaping this report. We are especially grateful to members of the Australian Hemp Council (AHC): Tim Schmidt, Ken Dods, Dick Clarke, Stuart Gordon and David Brian. We acknowledge valuable interactions with Harrison Marsh, Nicholas Keenan, Nicky Vandenburgh, Harriet Smith, John Muir, Guy Roth, Steve Allin, Johan Tijssen and the Nillumbik Shire Council.

Suggested citation:

Mancuso Tradenta, J. & Valenzuela, E. (2025*). Building Australia's Future: Industry Perspectives on Hempcrete Panels for Sustainable and Affordable Homes.* La Trobe Institute of Sustainable Agriculture and Food (LISAF), La Trobe University.

Executive Summary

This report explores the transformative potential of hempcrete panels for Australia's construction industry. Hempcrete, a bio-composite material made from hemp hurd, lime, and water, is positioned as a sustainable and innovative solution to address critical challenges, including reducing environmental impact and improving housing affordability.

As a renewable resource, hempcrete offers several advantages, including significant carbon sequestration, minimal climate impact, excellent insulation, and fire resistance. It also has the potential to reduce construction costs by improving labour efficiency and lowering long-term expenses through superior energy savings.

The hempcrete panel industry is in its early stages in Australia, presenting an exciting opportunity to create a regionally regenerative and economically resilient construction model. This report evaluates the current state of the industry and outlines pathways for its development.

Key findings from stakeholder consultations identify the following opportunities:

- Scaling production will lower material costs, making hempcrete more competitive with traditional building materials.
- Investment in hemp processing and decortication facilities will enable scalability.
- Public education initiatives are essential for increasing understanding and demand for hempcrete's benefits.
- Integrating hempcrete into building codes will streamline the certification process.
- Prefabricated panels can help address labour shortages by reducing reliance on skilled workers.
- Collaborative research involving academia, government, and industry can significantly accelerate adoption, inform investment decisions and support a more sustainable construction industry in the country and for potential export markets.

The next steps to realise these opportunities include fostering collaboration among stakeholders, increasing investment in infrastructure, and implementing supportive government policies. By addressing these priorities, Australia can establish a thriving hempcrete panel industry that meets housing needs while advancing sustainability goals. Hempcrete's potential to reduce carbon emissions, enhance housing quality (including fire and pest resistance), improve affordability (through better-insulated homes), and support local economies makes it a cornerstone for building a greener, more affordable future for Australia.

Recommendations

The growing demand for sustainable construction and affordable modular housing in Australia presents a strategic opportunity for hempcrete panels to become a mainstream building material over the next 5–7 years.

- **Advancing standardisation** in panel dimensions, material composition, and production processes is crucial for industry growth. Internationally recognised standards, such as the International Residential Code (IRC, 2024), will streamline certification and enhance industry credibility.
- **Coordinated promotional efforts** of hempcrete's environmental and economic benefits—emphasising its thermal efficiency, fire resistance, and carbon sequestration potential—will address misconceptions and drive adoption.
- **Detailed life cycle assessments (LCAs)** will provide policymakers and industry stakeholders with quantifiable data on hempcrete's environmental advantages. Adopting vertically integrated supply chain models, as demonstrated in the Netherlands, can improve efficiency, reduce costs, and enhance product consistency.
- **Expanding production capacity** and investing in local decortication and processing facilities will enable hempcrete to become cost-competitive with traditional materials. Locating production hubs near hemp cultivation areas and urban demand centres will also help reduce logistical challenges.
- **Increasing industrial hemp cultivation** through multi-purpose farming for both seed and fibre will ensure the availability of raw materials. Government incentives and streamlined certification processes, similar to policies supporting hempcrete in the Netherlands, will accelerate industry growth.
- **Research collaboration between academia, government, and industry** will drive technical improvements, production optimisation, and innovative applications. This will support regional development and create green jobs.

  By capitalising on these opportunities, the hempcrete panel industry can achieve economic viability, help address the housing crisis, contribute to sustainability goals, and foster innovation in low-carbon construction.

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Glossary of Key Terms and Abbreviations

ABCB (Australian Building Codes Board) – The regulatory body overseeing the National Construction Code (NCC) and building standards in Australia.

ACCU (Australian Carbon Credit Unit) – A government-certified unit representing one tonne of CO_2 sequestered or avoided under approved methodologies.

BCA (Building Code of Australia) – A set of national requirements for the design, construction, and performance of buildings in Australia, covering aspects such as safety, health, amenity, and sustainability. It is part of the National Construction Code (NCC).

Bio-composite – A material made from natural plant-based components combined with a binder, such as hempcrete, which consists of hemp hurd, lime, and water.

Building Envelope – The physical barrier between the conditioned interior and unconditioned exterior of a building, affecting thermal performance and energy efficiency.

Carbon Footprint – The total amount of greenhouse gases emitted directly or indirectly by a process, material, or individual.

Carbon Sequestration – The process of capturing and storing atmospheric carbon dioxide, often measured in life cycle assessments of materials like hempcrete.

Circular Economy – A sustainability model that emphasises reducing waste, reusing materials, and recycling resources to minimise environmental impact.

Decarbonisation – Reducing carbon emissions in industries such as construction through sustainable materials and energy-efficient practices.

Decortication – The process of mechanically separating hemp stalks into fibres and hurd (the inner woody core), a key step in hempcrete production.

Embodied Carbon – The total greenhouse gas emissions associated with material production, transportation, and construction, excluding operational emissions.

Fire Resistance – The ability of a material, such as hempcrete, to withstand fire exposure and prevent the spread of flames.

GBCA (Green Building Council Australia) – An organisation promoting sustainable building practices and certification programs, including the Green Star rating system.

GHG (Greenhouse Gas) Emissions – Carbon dioxide, methane, and other gases released into the atmosphere, contributing to climate change.

Hempcrete – A bio-composite building material made from hemp hurd, lime, and water, known for its thermal efficiency, carbon sequestration, and fire resistance.

Hemp Hurd (Shiv) – The woody core of the hemp stalk used in hempcrete production, offering high porosity and insulation properties.

HVAC (Heating, Ventilation, and Air Conditioning) – Systems responsible for regulating indoor air quality, temperature, and humidity in buildings.

IRC (International Residential Code) – A widely used standard for residential construction, including guidelines for hempcrete panel integration.

ISO (International Organization for Standardization) – A global body that develops international standards, including ISO 14040 for life cycle assessments (LCA).

LCA (Life Cycle Assessment) – A methodology for evaluating the environmental impacts of a product throughout its entire life cycle, often applied to hempcrete panels.

LEED (Leadership in Energy and Environmental Design) – A globally recognized green building certification system that evaluates sustainability performance.

Modular Construction – A building method using prefabricated components, such as hempcrete panels, assembled on-site for efficiency and cost savings.

NCC (National Construction Code) – Australia’s primary set of regulations for building safety, sustainability, and efficiency.

NatHERS (Nationwide House Energy Rating Scheme) – Australia’s energy efficiency rating system for homes, with a 7-star standard for new builds.

Passive Design – An architectural approach that maximises natural heating, cooling, and ventilation to reduce reliance on mechanical systems.

Prefabrication – The process of manufacturing building components off-site, including modular hempcrete panels, to improve efficiency and reduce costs.

R-Value – A measure of thermal resistance in building materials; higher values indicate better insulation properties.

Renewable Material – A resource that can be naturally replenished, such as industrial hemp, making it a sustainable alternative to conventional building materials.

Retrofit – The process of upgrading existing buildings with energy-efficient or sustainable materials, such as hempcrete, to improve performance.

SIP (Structural Insulated Panel) – A prefabricated panel that provides both structural support and insulation, sometimes incorporating hempcrete as a core material.

Thermal Mass – A property of materials that enables them to absorb, store, and release heat, helping regulate indoor temperatures.

Vertically Integrated Supply Chain – A production model where different stages of manufacturing, from raw material processing to product delivery, are controlled by a single entity, optimising efficiency and reducing costs.

VOC (Volatile Organic Compounds) – Harmful chemicals emitted by some building materials; hempcrete has low or zero VOC emissions, improving indoor air quality.

Introduction

The Australian construction industry faces economic and policy challenges, including skilled labour shortages, rising material costs, and high interest rates. These pressures are compounded by the urgent need for sustainable building practices to align with Australia's commitment to reducing greenhouse gas emissions. As one of the largest contributors to climate change, the construction sector must innovate to reduce its environmental impact while addressing housing needs.

To achieve these goals, the sector must adopt renewable materials that lower carbon emissions and improve process efficiency. Industrial hemp offers a compelling alternative to traditional materials. With its high carbon sequestration, low climate impact, and excellent end-of-life management, hempcrete—a mix of hemp hurd, lime, and water—provides exceptional insulation, fire resistance, and sustainability benefits. Although hempcrete shows significant promise, its market penetration remains limited due to higher initial costs, insufficient awareness, and the need for stronger support policies. Addressing these barriers is vital to unlock hemp's full potential in Australian construction.

This study evaluates the current and future potential of hempcrete panels in Australia, offering insights into production, processing, and application. By examining international best practices and engaging with a diverse range of stakeholders—including researchers, producers, processors, building designers, and industry bodies—it highlights pathways to integrate hempcrete into mainstream construction.

Key findings emphasise the importance of scaling production to reduce costs, investing in infrastructure, and raising public, and industry, awareness about hempcrete's benefits. Additionally, supportive policies and streamlined certification processes are critical for broader adoption.

This report provides stakeholders with information needed to incorporate hempcrete panels as a sustainable, affordable building solution. By leveraging industrial hemp's unique properties, the Australian construction sector can address increasing challenges while contributing to a greener, more resilient future.

Background and motivation

The role of the construction industry in carbon emission targets

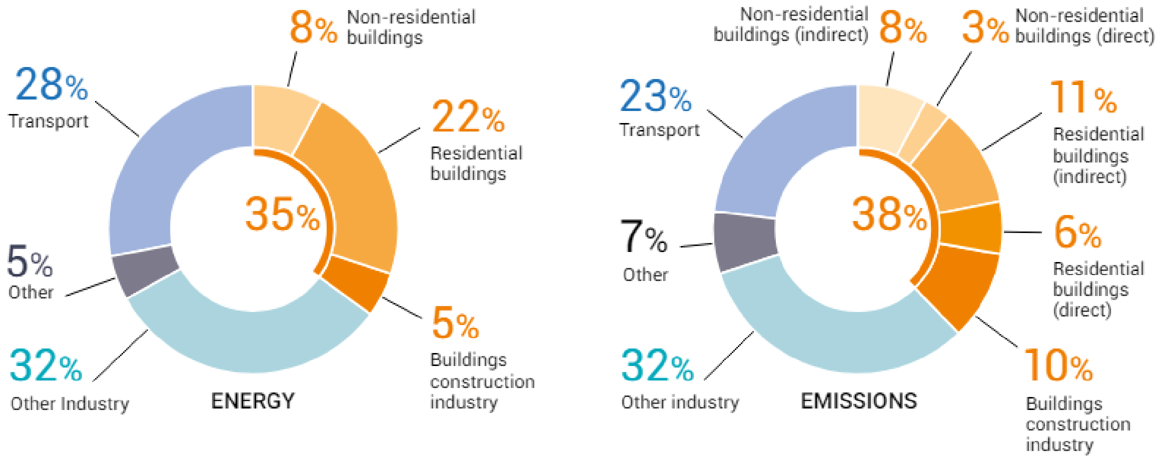
The global construction industry faces increasing pressure to reduce its carbon emissions, which contribute significantly to global greenhouse gas (GHG) emissions. The transition toward sustainable materials is a crucial part of this effort, and various regions and countries are adopting policies and practices to support decarbonisation. However, there is a disparity in the extent and effectiveness of these policies internationally, with the European Union (EU) leading the implementation of comprehensive measures aimed at reducing the construction industry's carbon footprint (UNEP, 2024a).

Embodied carbon and operational emissions

Buildings are responsible for a significant portion of greenhouse gas emissions. In 2019 the global buildings sector CO_2 emissions were 10 $GtCO_2$ (UNEP, 2022), which accounted for 28% of the total global energy-related CO_2 emissions, illustrated in Figure 1. When emissions from the construction industry are included, building-related emissions account for 38% of the total global energy-related CO_2 emissions (UNEP, 2022).

According to a 2022 report by the United Nations Environment Programme (UNEP), 26% of global construction industry and building emissions come from embodied carbon, while 74% come from operational carbon emissions. Embodied carbon and embodied energy refer to the total greenhouse gas emissions and energy used during the production of building materials, construction, and end-of-life stages (UNEP, 2024b). In contrast, operational carbon and operational energy are more visible as they represent the ongoing energy costs associated with running a building. Embodied carbon and embodied energy, on the other hand, are often overlooked, yet they represent the hidden impacts of buildings (GBCA & thinkstep-anz., 2021). These impacts are largely locked in before the building is even occupied. Reducing embodied carbon in construction materials used in residential buildings is critical as part of the industry decarbonisation process.

Figure 1: Global building and construction embodied energy and carbon emissions in 2019.



Source: UNEP (2022).

Global policy requirements for the construction industry to reduce emissions

Globally, reductions in carbon emissions across the construction and building sectors have largely focused on reducing the "operational carbon" of a building. Operational carbon is the emissions created from heating, cooling and lighting, with technological innovations reducing operational energy consumption projected to decrease carbon emissions from 75% to 50% in the next decade (UNEP, 2024b). Further reductions in operational carbon can be achieved with energy-efficient homes; incorporating materials that increase thermal efficiency is critical in reducing operational emissions from residential homes whilst reducing embodied carbon emissions. Currently, mass-produced homes are reliant on traditional building materials, which have higher embodied carbon (UNEP, 2022).

To increase the adoption of low embodied carbon materials, international construction codes and policies need to account for emissions generated during the production of building materials. Currently, there are no international agreements targeting emissions from the construction and building sectors, and global solutions for reducing embodied carbon in the industry are yet to be developed. Many of the United Nations Nationally Determined Contributions (UN-NDCs) under the Paris Agreement do not include specific targets for reducing energy use in construction (UNEP, 2022). Nevertheless, recent initiatives are aiming to reduce embodied carbon in buildings. This requires measuring carbon emissions throughout the production of construction materials and across the entire building lifecycle. According to hemp industry representatives, developing international construction standards and robust methods for assessing lifecycle carbon emissions will be crucial in promoting sustainable building practices.

Applicable solutions to measure lifecycle emissions in the construction industry

Whilst not specific to the construction industry, international standards for measuring an activity's lifecycle emissions have been developed. The International Organisation for Standardization (ISO) developed two complementary standards to measure the carbon emissions and embodied carbon created over an activity's lifetime. The principles and framework of life cycle assessments (LCA) are described in ISO 14040; the requirements are set out in ISO 14044. An LCA typically includes four phases: the definition of objectives and the scope of the study, the preparation of a life cycle inventory (an inventory of inputs and outputs), the impact assessment, and finally, the evaluation. LCA has been used by a range of organisations globally to evaluate the embodied carbon and carbon emissions within the construction and building sectors. However, the measurement of embodied carbon and lifecycle carbon emissions requires further work to develop a globally representative measurement process for the construction sector with Prasad et al. (2021) and McKinsey and Company (2023) identifying inconsistencies across measurement methodologies currently used.

An alternative to the LCA described in ISO14040 is to develop benchmarks or baselines for carbon emissions throughout the construction process and associated lifetime carbon emissions. These benchmarks can use existing standardised construction processes and resultant carbon emissions. The UNEP (2024a) suggests that by developing benchmarks, it can support the reduction of embodied carbon in building materials. The net-zero targets by 2060 are achievable if governments prioritise the development and use of the best available technologies for decarbonising conventional materials, combined with a major push to advance the increased use of regenerative, circular biomaterials from forest and agriculture streams (UNEP, 2024b). The UNEP (2024b) suggests that policies increasing investment in production technologies to redirect global biomass residues into cost-competitive construction products such as cementitious binders, bricks, panels, and structural components will support the decarbonisation of the construction industry. The compounding benefits of investment in less carbon-intensive construction materials include carbon storage and reduced climate change emissions. Developing standards and benchmarks for the construction industry to measure and report changes in embodied carbon in the construction process is an important step to support the construction industry in its decarbonisation.

International policies for energy efficient and decarbonised buildings

The United States (US) has limited federal policies specifically targeting the decarbonisation of the construction industry. The Department of Energy (DoE) provides information on improving housing energy efficiency, but there are no specific national standards for residential dwellings (DoE, 2023). Despite this, a range of biomaterials are used in residential construction in the US (US Hemp Building Association, 2024). Biomaterials, including hempcrete panels, are being used in residential construction in the US, following the standard set out in the *International Residential Code Without Energy, Appendix BL: Hemp Lime Construction* (IRC, 2024). The IRC is the foundation for the residential construction code in 48 states in the US. The US Hemp Building Association (2024) recommends that the hempcrete industry use this code as a basis for their construction projects and provides insight into how biomaterials that are not in existing construction codes can be used in the design and construction process.

In contrast, the European Union (EU) has developed construction policies aimed at transforming its building stock into a more energy-efficient and decarbonised state by 2050. As part of these efforts, the EU requires that all buildings for rent or sale possess an energy performance certificate, which indicates the building's energy efficiency level (ECA, 2020). The EU's policies focus on retrofitting existing buildings, combined with new buildings constructed with zero emissions by 2030 (ECA, 2024).

A range of sustainable materials and construction methods are being promoted to achieve the energy efficiency and zero-emissions standards required by the EU. The European Commission's Level(s) framework provides a comprehensive approach to evaluating the sustainability of buildings, focusing on the entire life cycle of a building, from construction to demolition (Grazieschi, 2023). This framework encourages the adoption of eco-friendly materials and practices that minimise the environmental impact of buildings.

One key strategy being adopted by the construction industry in the EU to reduce embodied carbon is by using bio-based materials. These materials, such as wood, soil, clay, cellulose (from recycled paper products), sheep wool, and hemp, offer a lower carbon footprint compared to traditional construction materials like concrete and steel (Grazieschi et al., 2021; Peñaloza et al., 2016). Wood and hemp are gaining traction as a sustainable building material due to their carbon capture capabilities and renewable nature (Grazieschi, 2023). Bio-material strategies being adopted by the EU construction sector provide important insights into how the Federal

Government and Australian construction sector can integrate natural renewable materials into policies for residential home construction to improve industry sustainability.

The role of new construction materials

The methods and materials being developed in the EU have the potential to be adapted and applied in other regions, including Australia, although different climates and construction needs will require tailored approaches. The United Nations Environment Programme (UNEP, 2024b) identifies three main principles for decarbonising construction globally:

1. "Avoiding" emissions through circularity,
2. "Shifting" to sustainable materials, and
3. "Improving" the production of extractive materials.

This provides an opportunity for bio-based materials like hempcrete panels to be used as part of Australia's construction industry decarbonisation.

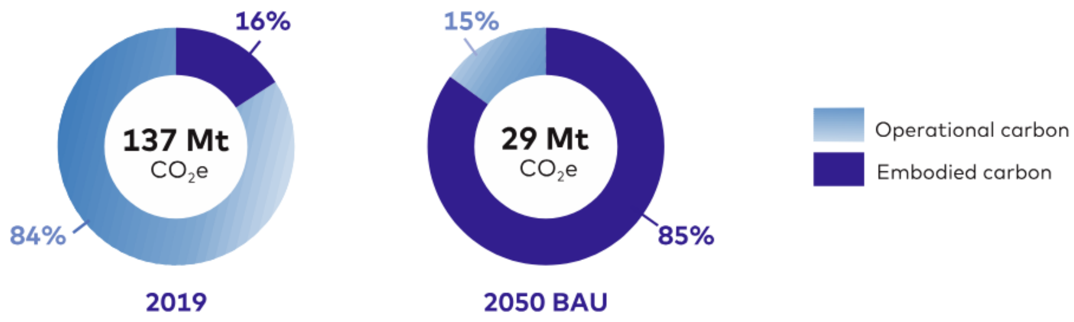
In developed countries, the focus will likely be on renovating existing buildings to improve energy efficiency. The McKinsey & Company (2023) report cited previously highlights the importance of collaboration across the global supply chain, involving financial institutions, manufacturers, and local governments, to stimulate demand for sustainable building materials and technologies.

The shift toward sustainable materials and construction practices is essential for reducing the global construction industry's carbon footprint. While the EU is leading the way with comprehensive policies and innovative projects, broader international cooperation and policy development are needed to achieve global decarbonisation goals. Australia and other regions are continuing to adapt and implement these practices, and the construction industry will play a pivotal role in combating climate change.

Role of the construction industry in reducing emissions in Australia

According to the 2021 report produced by Green Building Council Australia (GBCA) and thinkstep-anz., 16% of the total building carbon emissions in Australia in 2019 came from embodied carbon. This figure is expected to increase to 85% by 2050 if existing construction practices (business-as-usual, BAU) continue, with operational emissions expected to decline from 84% in 2019 to just 15% in 2050[1]. Estimates reported by *GBCA and thinkstep-anz. (2021)* are illustrated in Figure 2. These include operational emissions from all commercial and residential buildings across Australia in 2019 and projected for 2050, as well as embodied emissions from new constructions. Data from the Australian Government Department of Climate Change, Energy, the Environment, and Water (DEECCW) shows that buildings account for around 19% of total energy use and 18% of direct carbon emissions in Australia (DCCEEW, 2024).

Figure 2: Existing construction methods residential housing lifecycle carbon emissions in 2019 and projected emissions in 2050 with Business-as-Usual Scenario.



Source: GBCA & thinkstep-anz. (2021).

Construction industry carbon policies, standards and regulations in Australia.

The Australian Government has used international standards discussed previously, including ISO 14040 and Australian Standard (AS) ISO 14064, for greenhouse gas emissions calculation and reporting methods (Climate Active, 2022). These international standards have been used to develop a guideline for how to calculate carbon-neutral buildings (Climate Active, 2022). Other standards that have been considered include *The National Greenhouse and Energy Reporting Act 2007* and *ISO 14065:2013 – Greenhouse gases – Requirements for greenhouse gas validation and verification bodies for use in accreditation of other forms of recognition* (Climate Active, 2022).

[1] The business-as-usual (BAU) scenario in the GBCA & thinkstep-anz.'s report (2021) was designed to show what could happen by 2050 if new building construction grows in line with population forecasts and the primary focus for decarbonisation is achieving 100% renewable electricity generation by 2050. It assumes no changes in building practices from 2019, no electrification of process heat, and no carbon capture. Electricity emissions include "scope 3" GHG emissions from manufacture of photovoltaic panels, wind turbines, and other capital goods for renewable energy generation.

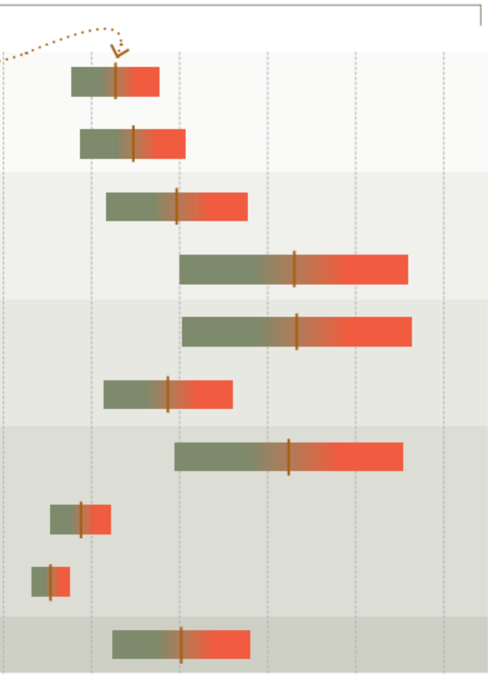
Meeting these standards is necessary for Australian Carbon Credit Unit (ACCU) certification. As illustrated in Figure 3, low-rise multi-residential buildings and offices have the highest embodied carbon out of any building classification in Australia.

As part of a decarbonisation strategy, the Australian Government is implementing policies to reduce operational carbon emissions in the construction industry. However, there is an opportunity for the Australian construction sector to further reduce emissions by, for example, adopting some of the EU industry processes, including the adoption of biomaterials such as hempcrete. In its report to the Australian Government, KPMG (2023) recommends that the Australian construction and infrastructure industry integrate global initiatives such as the ones discussed in the previous section to reduce embodied carbon across the sector into construction processes. The Green Building Council of Australia estimates that whilst architects are designing more sustainable buildings, there is a disconnect with industry, with some builders reluctant to change current construction practices. The Australian Government needs to consider methods to increase the uptake of biomaterials across the construction industry. This may include policies that have maximum embodied carbon allowable for new residential building developments.

Figure 3: Typical Australian embodied carbon by building classification.

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



Source: Prasad et al. (2021).

Australia's federal government construction codes and regulations

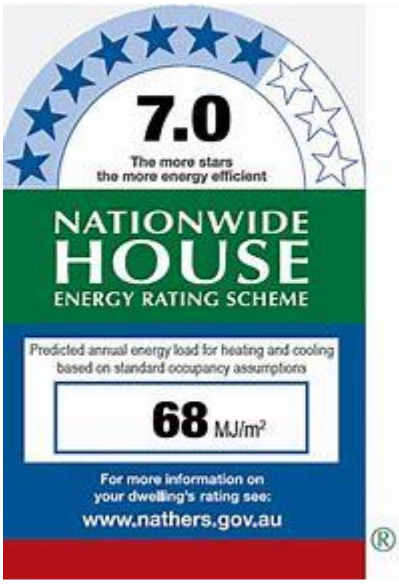
There are a range of policies and codes the construction industry needs to abide by at the national, state and local levels. The National Construction Code (NCC) sets out minimum requirements for safety, health, amenity, and sustainability in building design and construction across Australia. It is overseen by the Australian Building Codes Board (ABCB) (ABCB, 2023). The NCC is regularly updated to reflect advancements in building technology and changes in community expectations. Building products must be deemed 'fit for purpose', and evidence of their suitability must be established to demonstrate compliance with relevant requirements (ABCB, 2024). State and territory planning and building laws govern building activities and mandate compliance with the NCC for planning and building approvals. Building certification schemes, overseen by local councils or private practitioners, act as a 'check and balance' in the building process (ABCB, 2023). Consumer product safety is governed by the Australian Consumer Law (ACL). Suppliers must comply with ACL requirements, enforced by state and territory consumer protection agencies and the Australian Competition and Consumer Commission (ACCC). Conformity assessments managed by independent bodies or specialised schemes are recommended by the NCC for products seeking certification (ABCB, 2023).

Energy Efficiency Changes in the National Construction Code (NCC)

The NCC is the primary code governing the construction industry. In August 2022, State building Ministers agreed to support the Australian Government's goal to reduce greenhouse gas emissions by 43% by 2030 and achieve net-zero emissions by 2050 (ABCB, 2023). The NCC introduced new Performance Requirements and Verification Methods that promote innovation and sustainability in building design. These changes set quantified metrics for thermal performance and energy usage and provide clear targets for developers to meet energy efficiency standards (ABCB, 2024). New homes are required to meet a whole-of-home, annual energy use budget covering heating and cooling equipment, hot water systems, lighting, and swimming pool and spa pumps (ABCB, 2024). The NCC changes are flexible to enable solutions tailored to the climate and location of each building.

As part of an Australian Government initiative to improve residential home thermal efficiency, the Nationwide House Energy Rating Scheme (NatHERS) was established in 1993 (DCCEEW, 2024). NatHERS rates the energy efficiency of residential buildings on a scale from 0 to 10 stars. It assesses the thermal performance of homes, predicting their heating and cooling energy requirements based on design, orientation, and local climate (DCCEEW, 2024). As shown in Figure 4, a higher star rating indicates better energy efficiency, leading to lower energy costs and reduced GHG emissions. NatHERS aims to encourage the construction of more sustainable homes by providing a standardised method for comparing the energy efficiency of different designs and improving overall building performance.

Figure 4: Example Nationwide House Energy Rating Scheme (NatHERS) Product Certification.



Source: DEECCW (2024).

In 2022, the Australian Government lifted residential buildings' NatHERS certification from 6 to 7 stars, which is expected to significantly improve thermal comfort for occupants (DCCEEW, 2024). As part of the design process, new residential buildings will need to consider energy use across the house and ensure it is less than the average amount of energy used for a dwelling based on the number of bedrooms (Sustainability Victoria, 2023).

Proposed Changes to the National Construction Code (NCC)

The current NCC has raised energy performance requirements for residential homes, improving energy efficiency, which leads to savings on energy bills, better health outcomes, enhanced resilience to extreme weather, reduced carbon emissions, and lower investments in energy infrastructure (ACOSS, 2024). Although new NCC energy efficiency standards have increased construction costs by AUD 4,300 per home, they are expected to save about AUD 326 annually.

Proposed changes to the NCC 2025 will enhance energy efficiency, waterproofing, and condensation management in both commercial (Classes 3 and 5-9) and residential (Classes 1 and 2) buildings (HIA, 2024). Key amendments will enforce stricter requirements for commercial air-conditioning efficiency and insulation, while also mandating vapor permeable layers and improved ventilation for residential projects. Additionally, new homes and apartment parking will need pre-provisioning for electric vehicle (EV) charging, promoting sustainable building practices.

Current Construction Energy Efficiency

The energy inefficiency of Australian homes presents a significant health hazard, with 80% of existing dwellings having a 2-star energy efficiency rating. These dwellings have low energy efficiency increasing extreme weather exposure for residents. Exposure to extreme weather conditions can cause an increase in respiratory and cardiovascular diseases, such as pneumonia and high blood pressure, making the elderly, infants, and people with pre-existing conditions particularly vulnerable (Tidemann et al., 2022). In fact, heatwaves claim more lives in Australia than bushfires, floods, storms, and cyclones combined (Coates, 2014). Similarly, homes that cannot maintain warmth properly account for at least 6% of deaths in Australia each year (Gasparrini et al., 2015). The NCC 2022 changes requiring 7-star energy efficient homes will improve health outcomes during extreme heat.

Australia’s demand for sustainable construction materials

The demand for energy-efficient homes is on the rise in Australia, and several factors contribute to this trend. Research by Sustainability Victoria (2021) found that people are becoming more environmentally aware and want to reduce their carbon footprint. Furthermore, the cost savings associated with energy efficiency are significant, and this is an attractive proposition for homeowners. Additionally, government incentives, such as rebates and tax credits, make it more affordable for people to invest in energy-efficient features for their homes.

Sustainable construction practices are gaining popularity in Australia, and builders are increasingly using renewable resources (Langston & Zhang, 2021). This is due to an increased focus on reducing waste and environmental impact. Regions that are prone to climate change impacts like floods and bushfires have an even higher desire for renewable resources in Australia (Burroughs & Růžička, 2019). The commercial sector is also prioritising sustainability due to corporate social responsibility (CSR) initiatives and long-term cost savings.

Sustainability has become a crucial factor for Australian consumers with over 38% reporting that they always consider sustainability in their purchase decisions in 2022 (Statista, 2024). However, Sustainability Victoria (2019) found that consumers are confused by terminology that describes sustainable features and technologies, impeding the uptake of sustainable features in both new constructions and existing dwelling modifications. A further constraint is that home builders are locked into business models and supply chains that limit innovation, particularly with current market conditions with high construction costs as illustrated in Table 1 (Sustainability Victoria, 2019).

Table 1: Average cost per square metre to build a new home in Australia in 2023.

Construction type	Level of finish (AUD)		
	Low	Medium	High
3 Bedrooms (BR) weatherboard project home	1,817	2,034	2,516
3 BR brick veneer project home	1,936	2,157	2,576
3 BR full brick project home	2,012	2,235	2,794
4 BR weatherboard home	2,551	2,726	3,402
4 BR brick veneer home	2,711	2,839	3,573
4 BR full brick home	3,032	3,464	3,817
3 BR brick veneer project home	2,019	2,231	2,752
3 BR full brick project home	2,094	2,355	2,889
4 BR brick veneer home	2,834	3,203	3,718
4 BR full brick home	3,132	3,596	3,926
Architecturally designed executive residence	4,157	5,322	7,444

Source: BMT Quantity Surveyors (2023).

Many sustainable homes are bespoke, architecturally designed residences, which in 2023 were the most expensive residential dwellings to construct (BMT Quantity Surveyors, 2023). Whilst some larger construction companies can tailor construction to include sustainable features, industry professionals have found these incur additional costs and have less demand than insulation, energy-efficient lighting, and heating. These factors impact market demand for sustainable homes across Australia.

At present, there is a discrepancy between the increasing architectural need for renewable and sustainable materials such as hempcrete panels and their adoption speed in the construction industry. Builders generally lean toward traditional practices with established supply chains. Despite the demand for renewable resources in bespoke construction projects, hemp building sector participants noted there are supply chain gaps, leading to a lack of readily available standardised hempcrete panels and other materials. They identified further that another potentially short-to-medium term constraint is the current high level of mortgage interest rates, limiting new homes demand, influencing consumers' preference for cost-efficient housing designs Australian Government housing policy and the prefabricated modular building option

The Australian Government has agreed to a National Housing Accord with states and territories, aiming to build one million new homes over five years starting from mid-2024 (The Treasury, 2024). The Government will provide AUD 3.5 billion to support the delivery of new homes and has committed AUD 350 million to support the delivery of 10,000 affordable homes, with the potential for an additional 10,000 (The Treasury, 2024). These goals have increased demand across the construction industry. A survey by Navaratnam et al, (2022) of 310 construction professionals revealed that prefabricated construction offers benefits such as reduced construction time, high levels of quality control, and reduced on-site noise and disruption compared to traditional construction.

The New South Wales (NSW) Government is addressing the housing crisis by investing AUD 10 million in modular social housing. The NSW Modular Housing Taskforce, formed last year, is working to overcome regulatory barriers and set standards for these homes. The government aims to expand this program to provide more social housing across the state (Land and Housing Corporation, 2024).

Queensland's Modern Methods of Construction (MMC) program aims to build more and better-quality homes quickly to address Queensland's housing needs, especially in regional and remote areas. MMC focuses on using modular solutions, reducing waste, and creating a stable workforce. The program plans to deliver over 150 homes by mid-2024, partnering with various industry suppliers to manufacture homes efficiently and sustainably (Department of Housing and Public Works, 2024).

Similarly, in Victoria, to address a housing shortage, the Victorian Government is promoting the prefabricated construction industry. This approach is expected to reduce delays and waste, and contribute to Victoria's AUD 33.5 billion manufacturing sector, supporting over 260,000 jobs (Hutchins, 2024).

Despite the generally shared understanding of the adoption benefits of prefabricated panels, key barriers for their adoption have been identified in Australia. For example, the “reluctance or lack of awareness among Builders and Designers, policies of finance industry/banks, societal perception issues, risks in adapting to new processes and systems, and insufficient industry investment in research and development” (Dave *et al.* 2017). These barriers necessarily would need to be addressed to capitalise on this opportunity to enhance housing affordability.

Hemp-based construction materials as a potential solution

The goals of affordable housing are closely connected to environmentally friendly "green building" principles. However, in Australia, the relationship between these two concepts has only been partially explored (MacAskill et al., 2021). The adoption of green building practices is a key factor in achieving these goals (Clune et al., 2023). In Australia, hemp-based construction materials are emerging as an environmentally sustainable and innovative solution for residential housing construction, offering numerous environmental and performance benefits.

> *“Hemp is gaining recognition as a sustainable construction material that can significantly reduce embodied carbon and increase thermal efficiency. Hemp, a fast-growing and renewable plant, offers numerous environmental benefits when used in building construction”* (Hemp construction industry representative, 2024).

Warwick (2023) interviewed Professor Rachel Burton from the School of Agriculture, Food and Wine, at The University of Adelaide.

> *“Hemp is an extremely good insulator. It has been recognised that it controls humidity, and it provides a lovely living environment for humans. Hemp is fire retardant, so ideal for Australian conditions and other places that are hot and dry like California.”* Professor Burton.

Hemp applications in the construction industry

Hemp products offer a range of potential applications within the construction industry. Among other benefits, they can contribute to achieving green building standards while improving housing affordability. This affordability is linked not only to reduced construction costs—depending on market and supply chain conditions—but also to the ongoing use of housing over time, making hemp products an attractive option for sustainable building practices. By integrating these materials, the construction sector can promote both environmental sustainability and long-term economic viability. While the focus of this report is on the application of hemp as hempcrete panels (described in more detailed in the next sections), industrial hemp has a number of additional applications in the construction industry. Examples of these applications are listed the box below.

Applications of industrial hemp in the construction industry other than hempcrete.

Hemp Fibre Insulation: Hemp fibres are processed into insulation batts or rolls which are used in walls, roofs, and floors to improve energy efficiency and reduce noise. Hemp fibre insulation is a natural alternative to synthetic insulation materials.
Hemp Plaster: Hemp plaster is made by combining hemp fibres with lime or clay. Hemp plaster is used as an eco-friendly plaster for interior and exterior walls, providing a breathable surface that regulates humidity and improves indoor air quality.
Hemp-based Panels and Boards: Hemp fibres and hurds can be pressed into panels and boards, similar to plywood or MDF (medium-density fibreboard). Hemp panels are used for interior wall partitions and cladding. Panels and boards are also used to make furniture, cabinetry, and other interior fittings due to their strength and sustainability. Panels using patented mixture methods that do not include the lime component (i.e., to produce hempcrete) are being developed and produced in Victoria, Australia. These panels are already being used in several construction projects and structural and fire-resistance testing are being conducted, by Hexcore Pty Ltd., in collaboration with Victorian universities.
Hemp Flooring: Hemp fibres can be combined with other natural materials to create durable flooring options. Hemp-based flooring is used in eco-friendly construction projects, providing a natural alternative to traditional wood or synthetic flooring materials.
Hemp Wood: Hemp wood is a relatively new product made by compressing hemp fibres with resin to create a wood-like material. Hemp wood can be used in flooring, furniture, cabinetry, and even as structural elements in construction, offering a sustainable alternative to traditional timber.
Hemp-based Composites: Hemp fibres can be combined with other materials to create lightweight, strong composites. Hemp-based composites can be used in a variety of construction applications, including panels, insulation, and reinforcement materials.
Hemp Roof Shingles: Hemp fibres are used to create eco-friendly roof shingles. Hemp roof shingles offer a sustainable alternative to traditional roofing materials, providing durability and weather resistance.
Hemp-based Paints and Sealants: Hemp oil is used as a base for natural paints, sealants, and varnishes. These products protect wood and other construction surfaces while being eco-friendly and non-toxic.

Hempcrete characteristics and key benefits

Hempcrete is a bio-composite construction material made from a mixture of hemp hurd (the woody core of the hemp plant), lime-based binders, and water. It is used as insulation material in walls, floors, and roofs, providing excellent thermal performance and moisture regulation.

Hempcrete is often used in retrofitting and restoring old buildings due to its compatibility with traditional materials (Allin, 2012). It is commonly used in the construction of non-load-bearing walls for its breathability, weight, and energy efficiency. Load-bearing walls using hempcrete are also possible with some bricks, such as the ones produced by Cannabric in Spain (Allin, 2012) or hemp blocks like those produced by HempBlocks Australia. Hempcrete can be used in modular construction systems, allowing for quick and efficient assembly of buildings with the benefits of hempcrete's insulating properties.

Hempcrete mix

Hempcrete mix, as shown in Figure 5, is composed of approximately 80-90% hemp hurds (it can be processed into different types) and 10-20% lime-based binder by volume (Brain, 2021). The hemp hurds provide a highly porous structure, contributing to the material's excellent insulation properties and breathability. The lime binder, commonly a combination of hydrated lime (also known as lime putty or air lime and composed of calcium hydroxide) and sometimes hydraulic lime, (calcium silicates and aluminates) solidifies the mixture while allowing it to retain some flexibility. The primary distinction between the two lime binders lies in their setting mechanisms (Lime Stuff, n.d.). Hydrated lime is produced by adding water to quicklime, which is derived from heating limestone in a kiln, and it sets through carbonation. In contrast, hydraulic lime contains impurities such as clay or silica, enabling it to set and harden when exposed to water.

In addition to the aforementioned components of hempcrete, various other binders and additives are often used in its production, depending on the application. These may include clay, gypsum, cement clinker, volcanic ash (also known as pozzolan), gravel, and pigments (Allin, 2012 & 2014).

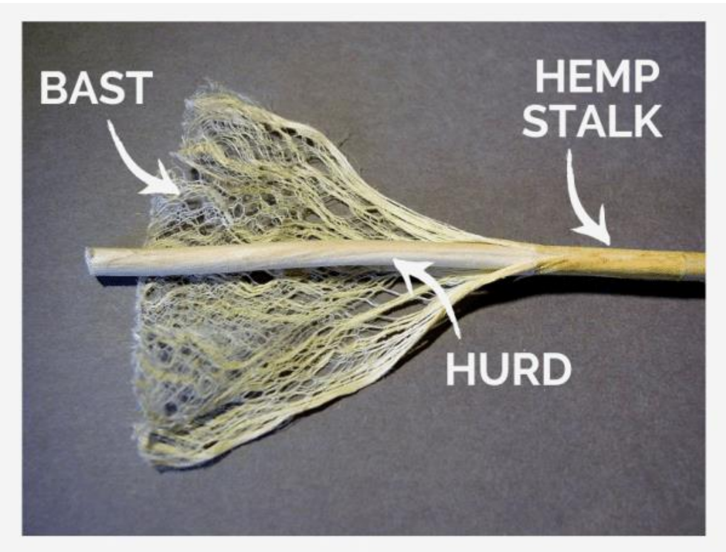
Figure 5: Hempcrete being prepared.

Photo courtesy of J. Tijssen.

Hemp Hurd

Hemp hurd, also known as hemp shives, is the woody inner core of the hemp plant's stalk (see Figure 6). Unlike the outer fibrous part of the hemp stalk (bast fibre), which is used in textiles and ropes, hemp hurd is commonly used for animal bedding, mulch, and in construction, particularly in hempcrete.

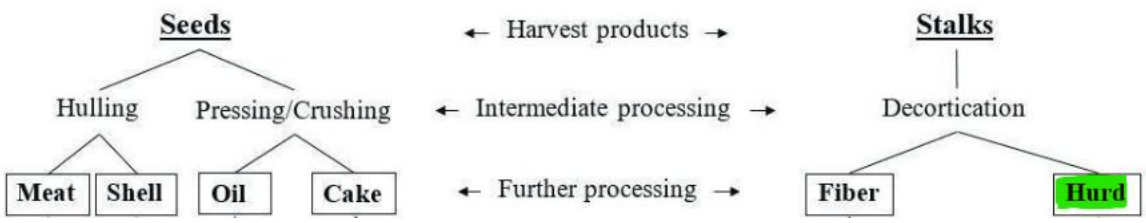
Figure 6: Hemp stalk composition.



Source: The Fiber and Hurd Council | Hemp Industries Association (2024).

Once harvested hemp plants need to be separated into their different parts through a process known as decortication. The decortication begins with the harvesting of mature hemp plants, which are then dried to prepare them for processing. During decortication, the dried stalks undergo a series of steps to extract the valuable bast fibres and the hurds (see Figure 7), with minimum or no cross-contamination. Decortication typically involves retting, where the stalks are soaked in water or exposed to dew to loosen the fibres from the core. Mechanical stripping or crushing is employed to separate the bast fibres from the hurds following retting. Once separated, both the bast fibres and the hurds are cleaned and processed into different industrial applications.

Figure 7: Hemp processing description.



Source: Fike (2019).

The size and proportions of the hurd particles obtained from the decortication process can vary depending on the hemp variety and the machinery used in the decortication process (Allin, 2012). Industry representatives note that the particle size and consistency of the hurds for the different applications in the construction industry are crucial. Figure 8 displays three examples of different types of hurd by size and application.

Figure 8: Hurd types and applications.

Particle size: Standard:
30mm x 10mm – 5mm x 1mm
Application: Casting

Particle size: Fine 15mm x
5mm – 3mm x 1mm
Application: Casting, Spray,
Plaster

Particle size: Extra Fine 5mm x
3mm – 1mm x 0.5mm
Application: Finish coat, Plaster

Source: Allin (2014).

Hemp growing advantages

Industrial hemp offers significant environmental benefits, with minimal reliance on pesticides, weed killers, fungicides and synthetic fertilisers. It also enhances soil health and supports biodiversity, promoting better agricultural practices (Essaghouri et al., 2023).

> *"Hemp is a sustainable option for building. We do not deplete the Earth's resources to produce hemp building materials. The plant regenerates soil, sequesters carbon during its growth cycle and the benefits continue into consumer products made from natural materials, creating healthy living spaces. The use of hemp building materials is a disruptor to the industry of traditional materials, and this is all coming at a time when our Earth is requiring changes to be made in order to confront the issues we have created in our environment"* (An International Hemp Builder).

Figure 9: Hemp harvesting

Photo courtesy of Johan Tijssen

Hempcrete's low embodied carbon aligns with Australia's goal of reducing emissions in the construction sector. Industrial hemp is a relatively fast-growing plant with high productivity per hectare. Reaching up to four metres in just 14 weeks, hemp produces around 15 tonnes of dry straw per hectare (see Figure 9 for an illustration of the hemp harvesting process). Industry estimates show that 1 ha of hemp produces enough material to support the construction of one standard house (Hempcrete Australia, 2023).

The Australian government has set a goal of constructing 1.2 million well-located new homes over the next five years, starting from mid-2024 (The Treasury, 2024). Based on the figures above and considering that approximately 672,000 hectares of arable land are currently dedicated to fibre crops (Department of Agriculture, Fisheries and Forestry [DAFF], 2025), hemp cultivation for building applications could significantly contribute to meeting this target.

Hempcrete embodied carbon

Studies indicate that hempcrete can be carbon-negative, meaning it stores more carbon than it emits during production and application (Ip & Miller, 2012). This contrasts sharply with traditional carbon-intensive materials like concrete. An emissions lifecycle assessment of a building constructed in the UK by Ip and Miller (2012) found that for a functional unit of hemp–lime wall of 1 m^2 and 0.3 m thick without any wall finishes, the net LCA generated in the growing, manufacturing and construction processes with the use of hemp-lime construction is positive, storing of 36.08 kg of CO_2e. Another LCA study in the United Kingdom by Bevan and Woolley (2008) showed a net reduction in GHG emissions over a 100-year lifespan, mainly due to the CO_2 storage in hemp. Hemp absorbs carbon dioxide during growth, storing it within construction elements.

Lime and hemp mixes used in construction can sequester carbon, with up to 165 kg of CO_2 per cubic metre in shuttered and cast hemp lime (Daly et al. 2013). Currently, standard residential construction processes emit 228 kg CO_2e / m^2 GFA, which is Kilograms of carbon dioxide equivalent per square metre of Gross Floor Area. As Australia phases in new energy efficiency requirements, embodied carbon in residential construction is projected to decline (GBCA and thinkstep-anz., 2021).

Thermal insulation and moisture regulation

Hempcrete possesses thermal and moisture-regulating properties, functioning as a natural air conditioner (Clune et al., 2023). Its capacity to enable walls to breathe contributes to the creation of a comfortable and healthy indoor environment, effectively regulating humidity levels within the structure to 40-60 % (Warwick, 2023).

In addition to moisture control, hempcrete provides excellent thermal insulation, which is essential for reducing energy consumption in residential buildings. Its high thermal mass helps stabilise indoor temperatures, decreasing the need for heating and cooling systems. Research suggests that homes built with hempcrete can achieve significant energy savings due to its outstanding thermal performance (Walker & Pavia, 2014). The material's thermal conductivity ranges from 0.06-0.12 W/m·K, making it a highly effective insulator compared to conventional materials like concrete or brick (Walker & Pavia, 2014). This low conductivity is due to the porous structure of hemp hurds, which trap air and slow heat transfer. This characteristic is particularly beneficial in climates such as Australia with significant temperature variations between day and night.

Building operational energy savings

Estimations indicate that a standard house built with brick veneer requires a one-tonne heating, ventilation, and air conditioning (HVAC) unit for every 46.5 square metres. In contrast, a house constructed with hempcrete requires only a one-tonne HVAC unit for every 140 square metres. This translates to a reduction in heating and cooling costs of approximately 68% (Hempcrete Victoria, 2024). Other reports suggest similar savings, with up to 70% reductions in heating and cooling energy consumption when using hempcrete (IsoHemp, n.d.).

A typical standalone suburban household comprising two adults and two children consumes just over 15,000 kWh of energy annually (excluding alternative energy sources) (Red Energy, 2024). Of this, around 40% is used for space cooling and heating, equating to approximately 6,000 kWh (Energy Rating, 2024). With electricity prices varying across states, reaching up to 34.84 cents per kWh (Momentum Energy, 2024), the average annual expenditure on space cooling and heating for a typical household would be around AUD 2,090. Consequently, a house built with hempcrete could save approximately AUD 1,463 annually in energy costs, providing significant savings, particularly beneficial for lower-income families (Clune et al., 2023).

Sound insulation

Hempcrete walls exhibit significant acoustic absorption. Unrendered hemp concretes have an average sound absorption of 40-50% of the normal incident signal across a range of frequencies (Medium, 2022). Hemp insulation has a density of approximately 35 kg/m^3 (2.18 lbs/ft^2), making it an effective sound dampener for acoustic applications (Medium, 2022).

A study by Glé et al. (2018) shows that hemp concretes have a significant effect on the acoustical performance. For example, hemp-clay and hemp-lime mixes behave similarly in terms of sound absorption and transmission. These properties make hempcrete a viable option for improving sound insulation in residential buildings.

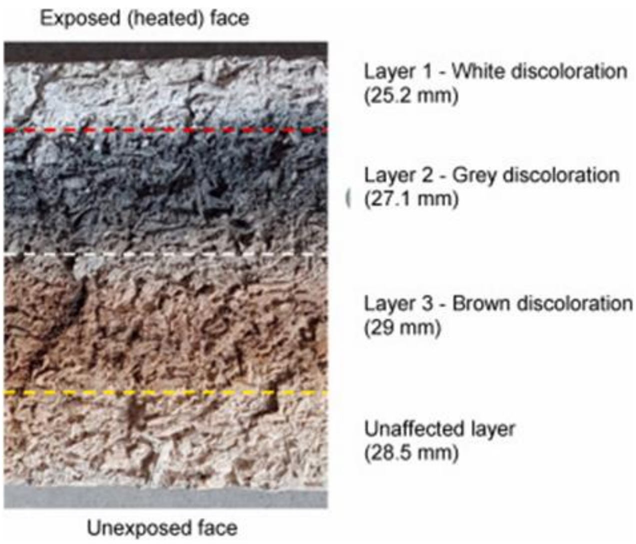
Fire resistance

Unlike traditional timber, which is highly flammable, the hempcrete panels' fire resistance of up to 2 hours, depending on the thickness of the panel (Walker, 2021), is a critical requirement for building materials in fire-prone areas. For example, this is a crucial feature in areas such as the

Nillumbik Region in outer northern Melbourne, where the 2009 Black Saturday bushfires occurred.

Hempcrete has been found to have a one-hour fire resistance rating according to the American Society for Testing and Materials (ASTM) standard. During fire tests, the exterior face of hempcrete panels did not exceed ambient temperature when exposed to intense heat (Souza, 2021). Current data indicates that hempcrete could achieve up to 120-minute fire resistance (Shewalul et al., 2023; House, Home and Garden, 2024). A cross-section through hempcrete exposed to fire for 120 minutes is shown in Figure 10.

Figure 10: Effect of 120 minutes exposure of hempcrete to fire.



Notes: "*White discoloration (layer 1) indicates that the hemp block underwent thermal degradation and turned into ash. The material is completely consumed and no longer exhibits structural integrity.*

Grey discoloration (layer 2) indicates that the hemp block has undergone charring, the surface of the material is partially burned, but the underlying material is still intact. This can provide a degree of fire resistance because the charred layer can act as an insulating layer that slows down the rate of heat transfer to the interior of the material. However, if charring is extensive, it can weaken the structural integrity of the material and increase the risk of collapse.

Brown discoloration (layer 3) indicates incomplete combustion, which means that the material is partially burned. The cream colour indicates the unaffected portion of the hemp block. This indicates that the outer section of samples was not significantly affected by heat and can potentially provide a barrier against the spread of fire and smoke".

Source: Shewalul et al. (2023)

Mould and pest resistance

Hempcrete boasts a pH level of approximately 12, creating an unfavourable environment for mould proliferation (Hemp Homes, 2024). Typically, mould requires a pH level of 4.5 or lower to thrive. The alkalinity of lime in hempcrete also plays a role in its resistance to pests (Hemp Homes, 2024). The elevated pH level and the inherent properties of lime combine to create a challenging environment for insects and rodents to inhabit or cause damage to hempcrete structures (Duani et al., 2024).

Moreover, hempcrete exhibits excellent moisture buffering capacity. It effectively stabilises relative humidity and minimises the risk of condensation, thereby providing an additional layer of defence against mould growth (Duani et al., 2024).

Toxicity

The toxicity of hemp and lime processing and use in construction is limited to the production of dust. They can irritate inhalation routes and form part of photochemical oxidants. Hemp lime bio-composite is a natural material with no or very little toxicity or off-gassing. Therefore, its toxicity during the demolition process is very limited (Daly et al., 2013).

Health properties

According to research by Bevan and Woolley (2008), hemp lime's impact on indoor air quality is generally positive due to its ability to allow vapour to pass through and its hygroscopic nature. This helps to balance humidity levels and prevent condensation, restricting mould growth. This natural moisture management improves indoor air quality, particularly in Australia’s diverse climates, from humid coastal areas to arid inland regions (Evrard, 2017).

Durability, re-use and recycling

Hempcrete has a minimal environmental impact when sent to a landfill. The mix can also be recycled by composting, backfilling, or spreading on flower beds or fields as a mulch to increase soil pH (Daly et al, 2013). Alternatively, it can be dispersed on land or agricultural fields where the hemp shiv biodegrades, and lime blends with the soil. Hemp lime mix can be crushed, mixed with water and additional lime binder, and reused in building processes including monolithic walls, bricks, and blocks.

In terms of durability, hempcrete is resistant to pests, rot, and decay, offering a longer lifespan than conventional materials. This durability reduces the need for frequent repairs or replacements, lowering the long-term environmental impact and costs associated with building maintenance. With low embodied carbon, excellent thermal performance, natural fire resistance, and durability, hempcrete is well-suited to meet the growing demand for eco-friendly and energy-efficient homes. Industry representatives have found the overall embodied carbon of hempcrete panels is significantly reduced, contributing to lower greenhouse gas emissions in the construction sector.

Hempcrete applications

Hempcrete can be used in residential construction with different methods. Five different methods, including hempcrete panels, which is the focus of this report, for creating hempcrete buildings are summarised below.

1. **Monolithic Cast Walls (In-situ, Wet-mixed Hempcrete Pouring)**: A common method where hempcrete is poured into formwork attached to the structural framing (Figure 11). It requires on-site mixing and setting, with drying taking up to three months (Hempcrete Walls: Building Journal, n.d.).

Figure 1110: Monolithic cast walls.

Source: Retrieved from https://hempcretewalls.com/info/

2. **Hempcrete Bricks and Blocks**: Pre-made, non-structural hempcrete bricks (Figure 12) are commonly used as wall infill and insulation. A negative carbon load-bearing hempcrete block system has been developed in Australia, which is claimed to be the first in its type in Australasia (Hemp Block Australia, 2024).

Figure 1211: Hempcrete Blocks.

Source: Retrieved from https://hempblockaustralia.com/

3. **Spraying Hempcrete:** Industrial spray equipment is used to apply hempcrete (Figure 13), offering faster application and better insulation. This method is proven in France and now adopted in North America, though it requires specialised equipment and expertise (Hempcrete Walls: Building Journal, n.d.).

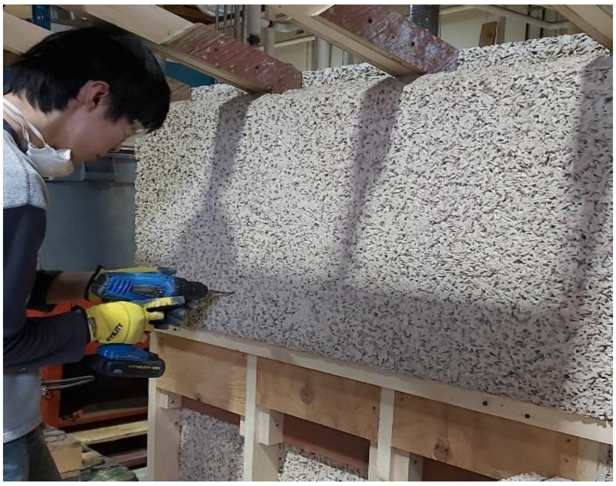
Figure 1312: Hempcrete Spraying

Source: Lupu et al. (2022)

4. **Non-structural Insulating Panels (NSIP):** NSIPs refer to hempcrete panels employed in non-load-bearing walls, partition walls or other areas where benefits of hempcrete, such as thermal insulation and moisture regulation, are needed, without requiring structural support. NSIP panels can also be attached around a load-bearing frame (such as timber or metal) on one of both sides of the frame (Figure 14). NSIP panels can be pre-manufactured in controlled environments and then attached to frames *in situ*.

Figure 1413: Non-structural Insulating Panels (NSIP)

Photo courtesy of David Brian.



Source: Retrieved from hempcretewalls.com/info/

5. **Structural Insulated Panels (SIPs):** SIPs on the other hand, are load-bearing pre-manufactured panels providing both insulation and structural support (Figure 15). SIPs may be fabricated with a layer of hempcrete sandwiched between two structural facings (usually timber or metal), where the core of the panel provides excellent insulation, while the outer layers contribute to the panel's strength and rigidity.[2] Hempcrete SIPs are more commonly manufactured by laying wood frames flat and filled with a hempcrete mixture. However, even when exclusively considering this type of panels, their structure and design vary significantly across producers.

More generally, both hemp NSIPs and SIPs provide benefits to the construction industry, despite their differences in structure, with varied applications and potential performance differences.

"Both panel methods leverage the benefits of hempcrete. Hemp panels offer a solution for reducing embodied carbon and increasing thermal efficiency in the Australian

[2] An example of a company producing sandwich SIPs in Australia is Kosp Construction Resources.

construction sector. By leveraging the natural properties of hemp, these panels provide a sustainable alternative to traditional building material" (Hemp construction industry representative, 2024).

Members of the hemp construction industry indicated that refabricating panels in a factory-controlled environment allows for precise and standardised manufacturing. Once produced, they are transported to the construction site and assembled quickly, which helps reduce construction time, labour costs and waste.

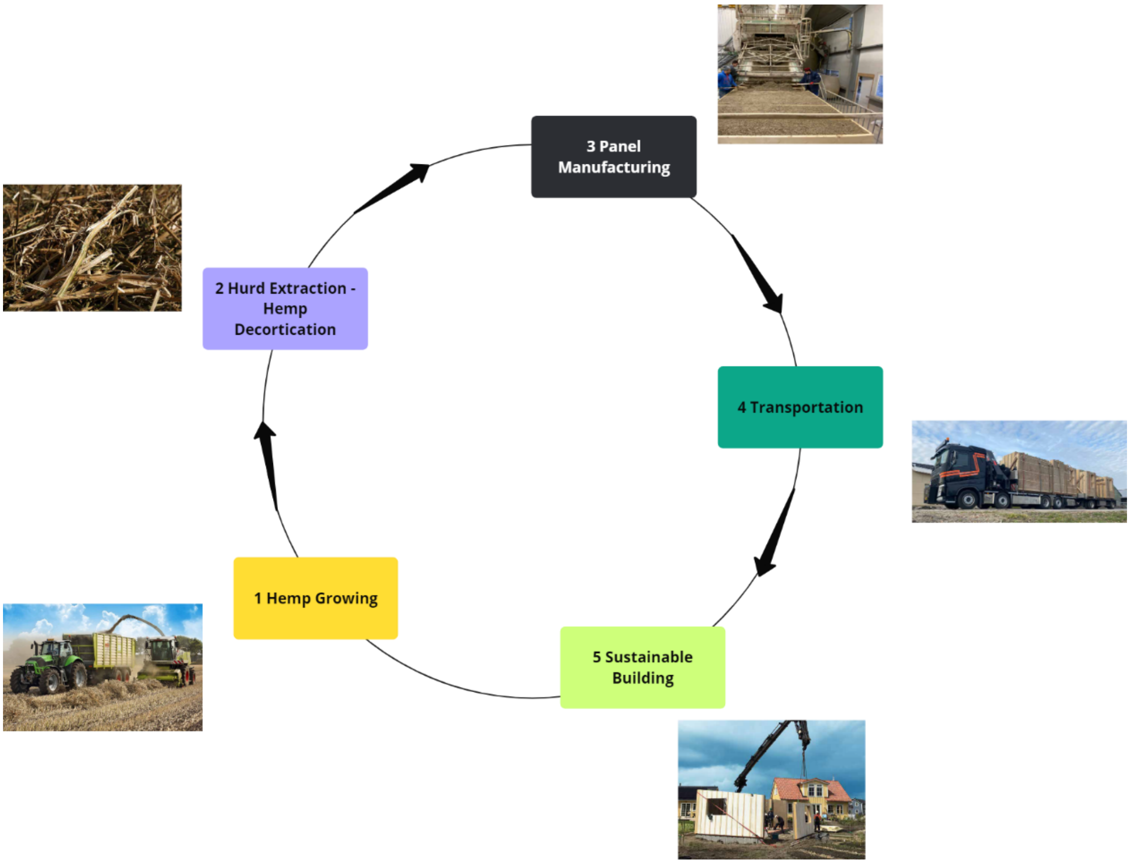
Figure 1514: Structural Insulated Panels (SIP) Prefabricated

Photos courtesy of Dun Agro, www.dunagrohempgroup.com/hemp)construction/

Panels supply chain

The supply chain of prefabricated Hempcrete panels can be defined in five stages (Figure 16): Growing, hurd extraction and decortication, panel manufacturing, transportation, and building.

Figure 15:Hempcrete prefabricated panels supply chain.



Source: Authors' illustration based on diagram and photos courtesy of Dun Agro, www.dunagrohempgroup.com/hemp)construction/

Stage 1: Hemp growing

Building a hempcrete house requires a significant amount of hemp hurds. The quantity of hemp needed depends on the size of the house, wall thickness, and the specific hempcrete mix used. Hemp construction industry representatives stated that sing current average industry production processes in Australia up to 14 metric tonnes of hemp hurds are required for each residential construction. They also found that that 1 hectare of hemp can yield between 10 to 20 tonnes of dry biomass, of which 30-40% might be usable as hurds (Daly et al., 2013). This suggests that building a single hempcrete house could require hemp grown on approximately 0.7 to 2 ha depending on the yield.

Stage 2: Hurd Extraction – Hemp Decortication

Processing hemp through decortication is a critical step in the production of hempcrete panels. Modern purpose-built machine-fed decorticators can process 1 to 2 tons of hemp per hour, making them highly efficient for large-scale operations (Marshall et al., 2019). The time taken for decortication in these facilities is optimised to handle continuous feedstocks with minimal downtime.

To establish an economically sustainable processing facility for hemp, it is crucial to develop multiple market-ready hemp products simultaneously. Hemp construction industry representatives indicated that relying solely on hempcrete as a single saleable item is not viable. The facility should consider including other products such as a finer form of hurd for injection-moulded plastic filler, hurd for equine bedding, and fibres for mats used in horticultural, soil erosion, and biocomposite applications. This approach allows each material type to be more cost-competitive and contributes to the overall profitability of the facility. In Canada, hemp hurd currently has significantly more commercial potential than fibres.

An alternative to purpose-built decorticators is to repurpose cotton gins, which, while capable of processing hemp, typically operate at slower rates (Marshall et al., 2019). Cotton gins are designed for the softer cotton fibre and may not handle the tougher hemp stalks as efficiently, resulting in lower throughput and longer processing times (Fike, 2016).

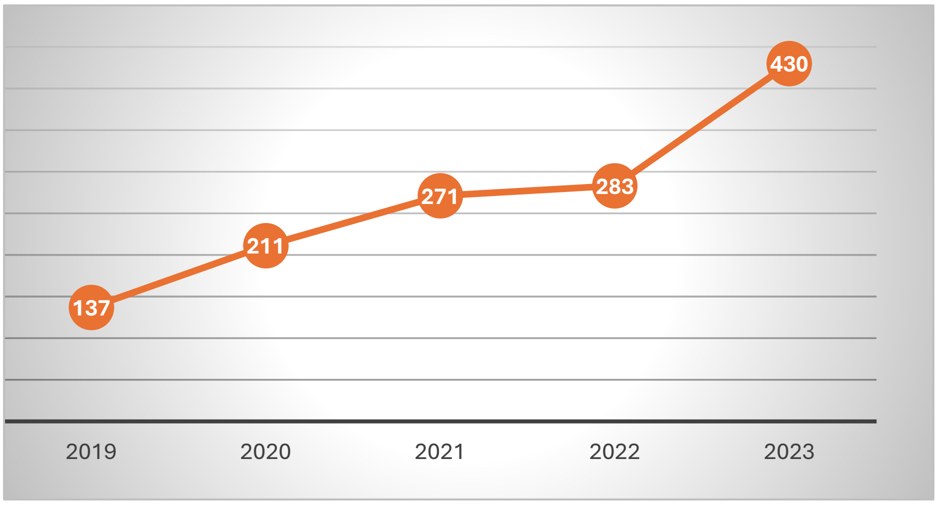
Energy consumption is a key factor in the decortication process. Purpose-built hemp decorticators are designed to be energy-efficient, consuming approximately 10 to 15 kWh per ton of hemp processed (Shahzad, 2018). Repurposed cotton gins may require more energy, estimated at up to 20 kWh per ton, due to their less efficient processing of the tougher hemp fibres (Fike, 2016). This higher energy requirement not only increases operational costs but also may affect the environmental sustainability of the hemp production process.

The cost of establishing a purpose-built hemp decortication facility in Australia can range from AUD 1.5 to 10 million, depending on the facility's capacity, technology, and location (RIRDC, 2017). In comparison, repurposing existing cotton gins presents a more cost-effective short-term solution. The cost of modifying a cotton gin to process hemp is estimated to be 50-70% lower than building a new facility (Marshall et al., 2019). However, these savings come at the expense of processing efficiency and product quality. Cotton gins can be repurposed to process hemp at a cost of approximately AUD 1 million, however, cotton gins are not designed for the rigid structure of hemp, which can lead to higher wear and tear on machinery, increased maintenance costs, and lower yields of usable fibre and hurds (Fike, 2016).

Australia's Opportunity for Import Substitution

Australia imports hemp products tariff-free under International Harmonised System (HS) code 5302, which includes hurd and other hemp materials (Australian Border Control, 2023).[3] Imports of hemp products into Australia increased significantly between 2019 and 2023, rising from USD 137,000 to USD 433,000 (Figure 17). This reflects growing domestic demand and market expansion, which have not been met by local production. The demand for imported hemp hurd, used in the production of hempcrete, is largely driven by the higher quality, consistency, and more competitive pricing of foreign supply.

Figure 1616: Hemp material imported by Australia - USD thousands (2019-2023).



Source: https://www.trademap.org/ with data from ITC calculations based on Australia Bureau of Statistics.

Historically, Australia's imports have predominantly originated from France and The Netherlands. However, imports from these countries dropped significantly in 2023, with South Africa emerging as the primary exporter, providing more than double the combined exports of France and the Netherlands (Table 2).

[3] The accurate tariff and statistical classification of hemp products is still work in progress. Ambiguity is still possible given the generalisation of the product description. According to UNCTAD (2022) "the United States Department of Agriculture (USDA) is currently working on a method to define more accurately and systematically different C. sativa L. cultivars or varieties."

Table 2: Australia's imports of hemp materials by exporter - USD thousands (2019 - 2023).

Exporters	2019	2020	2021	2022	2023
South Africa					277
Netherlands	117	150	143	143	96
France	9	20	95	104	26
Hungary					11
New Zealand				25	10
United Kingdom	6	13	11	7	2
United States of America				6	
Romania	1				
India			5		
Canada				1	
China	5	4			
Dominican Republic		2			

Source: https://www.trademap.org/ with data from ITC calculations based on Australia Bureau of Statistics.
Notes: HS 5302 True hemp "Cannabis sativa L.", raw or processed, but not spun; tow and waste of true hemp, incl. yarn waste and garnetted stock.

To be competitive in the local market, quality Australian hurd would need to be priced between AUD 1,600 and AUD 1,800 per tonne, aligning with the cost of imported hurd. Currently, according to hemp construction industry representatives, Australian hemp processors have the commodity priced at approximately AUD 2,600. Given that Australia has favourable conditions for cultivating industrial hemp, there is significant potential for import substitution in the hemp hurd market. By improving local production capabilities and achieving more competitive pricing, Australia could reduce its reliance on imported hemp products and better meet the growing domestic demand. Additionally, with the production of high-quality hurd, Australia could position itself as a future exporter, tapping into international markets and contributing to the global supply chain for hemp-based construction materials.

Stage 3: Panel Manufacturing

This hempcrete mixture is then pressed into panels, which are then dried and cured to achieve the desired strength and durability. The time to cure varies depending on product specifications. In the case of the panels manufactured by Dun Agro, the panels need to cure for 1.5 months before being ready for transportation.

The labour required to produce hempcrete panels, including decortication with a moderately automated facility, would require a workforce of 15-30 employees. These employees would be used across operations including material handling, machinery operation, quality control, and packaging (Marshall et al., 2019). Automated decorticators with integrated material handling systems can significantly reduce labour and increase throughput (Shahzad, 2018). Further productivity improvements could be through the installation of automated mixing and moulding systems and advanced curing systems, reducing the time between batches and increasing overall output (Shahzad, 2018).

The size and space requirements for a hemp panel production facility depend on the scale of operations. A medium-sized facility would require a footprint of approximately 2,500 m^2 to accommodate decortication, mixing, moulding, and curing processes (RIRDC, 2017). Additionally, space is needed for raw material storage, finished product storage, and equipment maintenance. According to international experts the total area required for the manufacturing facility may be up to 5.000 m^2, with an approximate equipment and capital cost to manufacture panels, including the building being USD 12 million.

The energy requirements for transforming hemp hurds into panels vary based on the scale of production and technology used. The entire process, from decortication to final panel production, is estimated to consume approximately 50-70 kWh per tonne of hemp hurds processed (Marshall et al., 2019).

Quality Assurance and Control

The quality control of hemp biomass, spanning from its cultivation to its integration into hempcrete products, necessitates meticulous monitoring and assessment. International manufacturers have identified that his includes ensuring traceability, managing the straw's moisture content at various stages, such as in the field, in bales, and during processing, evaluating its suitability for decortication, and determining the optimal process parameters and particle size.

Supply chain traceability is not currently a core requirement of the NCC, but it is increasingly relevant due to sustainability initiatives, compliance with international standards, and voluntary green building certification programs such as the GBCA (GBCA, 2021; ABCB, 2024). If hempcrete panels are to gain widespread acceptance, traceability systems for raw materials (such as hemp hurd and lime) will be important for certification and compliance with sustainability frameworks.

Product certification

The National Construction Code (NCC) in Australia outlines the technical design and construction requirements for buildings. The NCC certification process for building materials, including hempcrete panels, involves the following (ABCB, 2024):

CodeMark Certification Scheme: This voluntary third-party certification scheme ensures compliance of building materials, construction forms, and designs with the Building Code of Australia (BCA) Volumes One and Two. Products certified under CodeMark are nationally recognised as compliant with specific BCA requirements.

Types of Evidence: There are three types of substantiation or evidence that can be used to validate a product's conformity and compliance with the NCC:

- Certificate of Conformity by CodeMark or WaterMark
- Certificate of Accreditation from a State or Territory Accreditation Authority
- Certificate from an appropriately qualified person, such as an engineer.

> *"The panels and other building materials need to be tested and certified in the country they will be sold in. This testing process can take a year to complete. Building codes must be developed and need to adopt the materials as an approved alternative."* (An International Hemp Construction Industry Expert, 2024).

Tradical® Hempcrete is the first and only hempcrete material in Australia and New Zealand to conform to the BCA and be certified by CMI Certification to the CodeMark Australia Scheme (OzHemp, n.d.). Currently, under the NCC regulations, hempcrete is assessed for compliance with the NCC as a Performance Solution, similar to the approach required for the use of strawbale and earth-walled buildings (ABCB, 2024).

Stage 4: Panel Transportation

Transporting hemp hurd can be costly due to its high volume and relatively low weight. Because hurd is bulky, it takes up significant space, which increases shipping expenses, as transport costs are often calculated based on volume rather than weight. This makes efficient packaging and local production important to reduce transportation costs, particularly for long distances.

Similarly, industry representatives indicated that the transportation of hempcrete panels from the production facility to the construction site requires careful management. While hempcrete is durable once installed, the panels can be susceptible to cracking or breaking during transit due to their low tensile strength. Proper packaging, secure strapping, and padded transport systems (Figure 18) are essential to prevent damage.

Figure 1717: Hempcrete panels transportation

Photo courtesy of Dun Agro (www.dunagrohempgroup.com/hemp)construction/

Additionally, industry professionals have found that sourcing materials or locating production facilities closer to construction sites can further minimise transportation risks and costs. Careful logistics planning ensures that the panels arrive intact and ready for installation.

Stage 5: Panels building assembly

According to international producers the time and number of workers to assemble a 100 sq mt house requires 5 days of work with 4 people on site.

Hempcrete panels in Australia - current state and industry prospect

The hempcrete panel industry in Australia remains relatively small, with boutique manufacturers operating in several states. However, hemp construction firms have found that production processes are not standardised and currently lack certification under national or international standards. As a result, construction projects using hempcrete panels face a lengthy certification process, requiring early decisions during the design phase. According to a sustainability specialist in the building sector, to boost demand for hempcrete panels in residential construction, achieving certification is essential. This process is time-consuming and complex, even for large global companies like Dun Agro, and is expected to be particularly challenging for smaller firms.

Once certified, hempcrete panels can be included in building materials assessments, leading to wider adoption by architects. To transition from a bespoke product to a commercial product, hempcrete panels ideally need to have standardised panel sizes and production processes, including standardised hurd sizes and ratios of lime and hurds used in production.

According to Thomas & Ding (2018), the average lifecycle cost for a standard brick building with a 50-year lifespan before the NCC changes in energy efficiency requirements is AUD 832 / m^2. However, for a timber building, the average lifecycle cost is AUD 812 / m^2.

After the NCC changes to the construction code, Islam et al. (2022) estimated that it would cost an additional AUD 9,000 to improve a 6-star energy efficiency rating to a 7-star energy efficiency rating for a standard residential construction in Australia. Belusko and O'Leary (2010) found that the additional construction costs to improve energy efficiency in a 171-square-metre dwelling were AUD 7,500.[4] Research by the Climate Council (2022) found that increasing home thermal efficiency can result in annual operating cost savings of AUD 972 compared to an existing 2-star dwelling.

For hempcrete panels to be part of the mainstream production process, under current conditions, they will need to be competitively priced relative to currently used materials, as shown in Table 1. However, sustainability requirements in the construction industry are likely to become stricter over time, so in the next 5-7 years, new sustainable materials may be crucial to fulfil such requirements. Hempcrete panels is one of the few materials that aligns with the arising sustainability requirements. For construction cost changes to be moderated, government support in the early stages of industry development can help producers achieve competitive targets, with the expected need to increase the agricultural production of hemp.

To estimate a competitive price point for hempcrete panels in the next 5–7 years, a comparison with similar products, such as Hebel Panels, can be developed. [5]However, industry stakeholders argue that this approach does not fully account for the superior properties of hempcrete panels.

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[4] Note: construction costs in Belusko and O'Leary (2010) have been adjusted to 2023 dollars using the Reserve Bank of Australia average inflation rate for the period 2010 – 2023.
[5] In 2023, Hebel panels were estimated to cost approximately AUD 84 for a 75 mm tick panel (Clune et al. 2023).

In addition, a straight comparison misses the value of carbon sequestration. A more appropriate metric might consider the square metre cost of constructing a new building that meets all rating requirements of that period, ideally including the benefit of carbon sequestration and avoided emissions of using hempcrete instead of other materials. Detailed estimations for potential future scenarios fall outside the scope of this study.

Growing and processing

The agricultural industry is seeking to improve soil carbon and diversify land use, and hemp is a crop suited to irrigation areas in the Murray Darling Basin, and it has been suggested that hemp can generate yields of up to 20 ton/ha. However, the industry has identified a key barrier to increasing hemp production in Australia is the relatively low demand for hemp hurds and the restricted availability of processing facilities in hemp-producing regions. Further development of hemp agricultural production will require investment in decortication facilities in regions suitable for hemp production and the development of a market for hemp hurds. Irrigators across the Riverina in South Australia and other wine grape-producing regions are seeking to diversify incomes, especially with Australian wine grape supply exceeding international demand. There is an opportunity to expand hemp production in these areas and provide irrigators with a crop that can provide an alternative income stream.

For processing hemp crops, repurposing cotton gins offers an immediate and less expensive entry into the hemp processing industry. However, the long-term benefits of purpose-built decortication facilities are substantial. Purpose-built facilities ensure higher efficiency, better energy use, and more consistent quality of output, which are essential for meeting industry standards and supporting large-scale production. Additionally, the scalability of purpose-built facilities makes them more suitable for supporting the anticipated growth of the hemp industry in Australia.

Carbon Credits in the Hempcrete Supply Chain

Hempcrete's ability to sequester carbon throughout its lifecycle presents a unique opportunity for carbon credit generation within the construction supply chain. By quantifying the carbon storage potential and integrating it into the broader carbon market, stakeholders in the hempcrete industry—growers, processors, builders, and investors—can benefit from selling carbon credits. This mechanism can potentially incentivise the adoption of hempcrete in construction, reducing Australia's construction industry carbon footprint.

Carbon Sequestration and Credit Generation

Hemp plants sequester between 8 and 22 tonnes of CO_2 in a year, with wide variation due to differing cultivar types, management practices, soil and climatic characteristics (D'Amico, 2024). The Australian Carbon Credit (ACCU) scheme is the Federal Government certification process enabling primary producers and other eligible entities to register carbon sequestered. On 30 June 2024, the weighted average carbon spot price for an ACCU representing one tonne of carbon sequestered was AUD 36.25 (Clean Energy Regulator, 2024). Currently, hemp does not meet the Clean Energy Regulator carbon market requirements and, therefore, is ineligible for carbon credits. However, the Australian Government is reviewing an industrial hemp CO_2 sequestration method for inclusion in the ACCU Scheme (DCCEEW, 2024).

During the transformation of hemp into hempcrete, additional CO_2 sequestration occurs through the carbonation of the lime binder. This process, known as carbonisation, can continue for years after the hempcrete is applied in buildings, adding to the overall carbon storage potential (Arehart et al., 2020). The volume of carbon sequestered in the carbonisation process varies depending on the binder added and the density of the hempcrete mixture, however Arehart et al. (2020) found that between 0.15 to 0.47 kg CO_2/kg can be sequestered by hempcrete through carbonisation. Hemp shiv, binder and block production utilising fossil fuels create 41.50 kg CO_2 eq. per 1m^2 of hempcrete wall (Arrigoni et al., 2017). Transportation of hempcrete to the construction site using fossil fuel driven transport contributes a further 6.52 kg CO_2 eq. generating a net total of 48.02 kg CO_2 eq. per 1 m^2 of hempcrete wall (Arrigoni et al., 2017).

When considering the entire lifecycle of hempcrete as part of an LCA, including cultivation, processing, and transportation to its use in construction, the embodied carbon can be negative, meaning it stores more CO_2 than it emits (Arosio et al., 2022). Carbon sequestered as part of the mineralisation process can be used to offset any transport and construction emissions with any surplus carbon stored monetised through carbon credits. However, most of the carbon sequestration benefits are accrued to the primary producer growing the hemp. These benefits may remain with the landholder and be unrealised in the construction process. Developers and builders using hempcrete can construct carbon neutral buildings. This can enhance the sustainability profile of the project and support green building certifications like GBCA certification and contribute to the NCC 7-star rating.

Green building certification

Participation in carbon credit schemes requires adherence to robust verification standards, such as the “Green Start Rating” by the GBCA (Zuo et al., 2017). Independent third-party verification and monitoring are critical to ensure the credibility of the product, and the credits generated. A further benefit of independent certification is the growing demand for low-carbon construction materials, which can boost hempcrete's credibility and increase market demand. Companies focused on decarbonising their operations and supply chains may purchase hempcrete panels as part of their emissions offset strategies.

With differing construction methods across suppliers in the hempcrete industry, a key challenge is developing a standardised process to enable the accurate quantification of carbon sequestered. Without standardised processes, accurately quantifying the carbon sequestration in hempcrete, particularly the ongoing carbonation of the lime binder, will be challenging. Developing standardised methodologies and LCA tools specific to hempcrete is essential to enable further industry development and certification through processes like the GBCA “Green Star”. Establishing market access and securing buyers for hempcrete carbon credits may require building industry awareness and confidence in the material’s carbon benefits. Partnerships with sustainable building certifiers and carbon market platforms can facilitate this.

Opportunities and Strategic Pathways for Establishing the Hempcrete Panel Industry

The growing demand for sustainable construction practices and renewable resources in Australia, along with rising interest in affordable modular housing, provides a unique opportunity for hempcrete panels to become a mainstream building material.

This section identifies critical opportunities and required actions for the industry to develop over the next 5 to 7 years, supported by insights from industry stakeholders and international experiences.

Advancing standardisation in panel dimensions, material composition, and production processes is important for the industry's growth. Adopting internationally recognised standards, such as the International Residential Code (IRC, 2024), can streamline certification processes and improve trust among builders, architects, and regulators. The development of performance-based standards for Australian conditions will support wider adoption (ABCB, 2024).

An industry coordinated approach to promoting the environmental and economic benefits of hempcrete through targeted campaigns will address misconceptions and encourage adoption. Highlighting its thermal efficiency, fire resistance, and carbon-sequestration potential can appeal to policymakers and builders (Walker & Pavia, 2014; Warwick, 2023).

Detailed LCAs will quantify hempcrete panels' environmental benefits, such as carbon storage and low embodied emissions, providing essential data for policymakers and industry stakeholders (Bevan & Woolley, 2008).

Adopting vertically integrated supply chain models, as seen in The Netherlands, can optimise efficiency and innovation. Coordination among raw material suppliers, manufacturers, and construction firms is vital to reduce costs and enhance product consistency (Dun Agro, 2024).

Expanding production is essential to achieve the economies of scale required to make hempcrete panels sustainably cost-competitive within the next 5 to 7 years. According to industry participants, investment in local decortication and processing facilities will reduce dependence on imported hurd materials, achieving cost parity with traditional materials (AUD 1,600 – 1,800 per tonne). Establishing production hubs near hemp cultivation areas, lime quarries, and urban demand centres can reduce logistical challenges and transportation costs and the overall production cost of hemp panels.

The integration of regional processing facilities will also support rural economic development (Marshall et al., 2019). Expanding industrial hemp cultivation to meet demand for hurd will enhance raw material availability. Collaborative industry initiatives can encourage multi-purpose farming for seed and fibre, improving agricultural viability (Gordon et al., 2023).

Government incentives, such as grants or subsidies, and streamlined certification processes can accelerate the industry's growth. International examples, such as the Dutch government's support for hempcrete production, demonstrate the value of such policies. There is an opportunity to support the state and federal government initiatives for a rapid increase in housing supply through modular prefabricated hempcrete houses which meet the 7-star NatHERS efficiency standards required.

Research collaboration among academia, government, and industry presents a significant opportunity to advance the adoption of hempcrete panels and related technologies over the next 5 to 7 years. Further research can address technical challenges, optimise production processes, and explore innovative applications, while strengthening industry collaborations, promoting regional development, creating green jobs, and enhancing the resilience of local communities. These efforts will provide the evidence base necessary to guide policy development, shape market strategies, and support informed investment decisions, fostering sustainable and inclusive growth for the sector.

By addressing these opportunities, the hempcrete panel industry can achieve economic viability, contribute to Australia's sustainability goals, and drive innovation in low-carbon construction practices.

Conclusions

This report highlights the transformative potential of hempcrete panels in advancing environmental sustainability and addressing housing affordability in Australia. The construction industry is well-positioned to embrace renewable resources, such as hemp, by integrating hempcrete panels into building practices. These innovative materials offer a powerful pathway to decarbonise the industry and significantly reduce Australia's carbon emissions. Moreover, hempcrete dwellings provide substantial benefits for residents, including lower heating and cooling costs, enhanced fire and pest resistance, and healthier indoor environments that promote overall well-being.

Strategically establishing hemp panel production facilities near raw material sources and major construction sites can optimise supply chains, reduce costs, and enhance the competitiveness of hempcrete panels against traditional materials. The hemp panel supply chain offers broad benefits, from fostering local agricultural development to delivering sustainable, carbon-negative housing solutions, presenting a unique opportunity to increase Australia's housing supply sustainably.

While regulatory and certification processes need refinement, and standardised production practices are yet to be fully developed, these challenges represent growth opportunities. Increased public awareness and the establishment of regional hemp processing facilities could drive regional economic development through job creation and local investment. These efforts would align with broader sustainability and economic resilience goals, with import substitution serving as an additional benefit.

Looking forward, industry-wide collaboration will be pivotal to scaling hempcrete adoption. Engaging major construction firms, fostering cross-sector dialogue, and advocating for supportive government policies will help integrate hempcrete panels into mainstream construction practices. With strategic investments and innovative solutions, the hempcrete industry is poised for significant growth over the next 5 to 7 years.

Hempcrete panels can revolutionise Australia's construction industry, offering energy-efficient, affordable housing while supporting a regenerative, climate-resilient future. This report comprehensively assesses the industry's current state and outlines actionable recommendations to position hempcrete as a cornerstone of sustainable building practices in the years ahead.

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