25TH ANNIVERSARY

GECA

FINAL REPORT

Recycled Content Verification Study

Advisory services for optimisation of recycled content in building products in modular housing for Homes NSW Modular Dwellings

CARBON ANALYSIS SERVICES PROVIDED BY: Rebuilt®





ABOUT GECA

GECA, formerly Good Environmental Choice Australia, is an independent, purpose-driven not-for-profit established in 2000 with a clear vision – to help create a sustainable future for people and planet. With 25 years of experience, GECA works across the entire lifecycle of products and services to empower better choices.

We offer a suite of services designed for anyone committed to continuous improvement in their sustainability. GECA's lifecycle ecolabelling program – the first of its kind in Australia – certifies products and services against rigorous standards based on ISO 14024, covering environmental, health, and social impacts.

GECA has proudly been a Certified B Corporation since November 2015. Being a B Corp means we are part of a global community that meets high social and environmental performance standards, as well as accountability and transparency.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

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Certified B Corporation

This company meets high standards of social and environmental impact.

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This *Final Report: Recycled Content Verification Study* was prepared by GECA. The views expressed within are not necessarily the views of Homes NSW and may not represent department policy.

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Acronyms and Definitions

AS/NZS ISO 14021	Australian/New Zealand Standard ISO 14021 – Environmental Labels and Declarations – Self-declared Environmental Claims
ASI	Aluminium Stewardship Initiative (international certification and chain-of-custody standard for the aluminium value chain)
AusLCI	Australian Life Cycle Inventory (national background database used for embodied carbon modelling where product-specific data is unavailable)
ATEx	Technical Experimentation Assessment (France)
BCA	Building and Construction Authority (Singapore)
BF-BOF	Blast Furnace - Basic Oxygen Furnace
BOQ	Bill of Quantities (Itemised schedule of materials, products and quantities required for a construction project)
C&D	Construction and Demolition (C&D)
CE	Circular Economy
CFA	Conditioned Floor Area (floor area basis used in some embodied carbon benchmarks, e.g. GBCA's Our Homes Weigh a Tonne)
CIC	Construction Industry Council (Hong Kong)
CIMA	Cellulose Insulation Manufacturers Association
CLT	Cross-Laminated Timber (solid timber panels made by gluing layers)
DCCEEW	Department of Climate Change, Energy, the Environment and Water (Australian Government)
DfD	Design for Disassembly (designing buildings for easy dismantling and reuse)
DfMA	Design for Manufacture and Assembly
DNV	International certification and assurance body (formerly Det Norske Veritas), used to independently verify recycled-content claims such as Hydro CIRCAL
DRI	Direct Reduced Iron (alternative steelmaking process to blast furnace ironmaking)
EAF	Electric Arc Furnace
EPD	Environmental Product Declaration (standardised life-cycle environmental data disclosure)

Acronyms and Definitions

FSC	Forest Stewardship Council (forestry and timber chain-of-custody certification scheme)
FY	Financial Year
GBCA	Green Building Council of Australia
GEN	Global Ecolabelling Network (network of Type I environmental label organisations)
GHG	Greenhouse Gas (emissions contributing to climate change)
GFA	Gross Floor Area (floor area basis used in some embodied carbon benchmarks)
GWP	Global Warming Potential (measure of a substance's contribution to climate change, expressed as $kgCO_2e$)
ICT	Information and Communication Technology
IEA	International Energy Agency
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LCA	Life Cycle Assessment (analysis of environmental impacts across a product's life cycle)
LCI	Life Cycle Inventory (database of material and process environmental data used in carbon modelling)
MFA	Material Flow Analysis
MMC	Modern Methods of Construction (innovative off-site construction techniques, e.g. modular)
NABERS	National Australian Built Environment Rating System
NAIMA	North American Insulation Manufacturers Association
NCC	National Construction Code (Australian building code framework)
NSW	New South Wales (State of Australia)
OECD	Organisation for Economic Co-operation and Development
PCF	Product Carbon Footprint (platform/methodology used by Rebuilt to model embodied carbon for this project)

Acronyms and Definitions

PEFC	Programme for the Endorsement of Forest Certification (forestry chain-of-custody certification scheme)
PPVC	Prefabricated Prefinished Volumetric Construction (fully fitted volumetric modules)
PV	Photovoltaic (solar electricity generation)
PwRC	Products with Recycled Content (materials containing recycled material)
RMMT	Reusable Modular Mass Timber [system]
WRAP	Waste & Resources Action Programme (UK sustainability organisation)

1 Executive Summary

1.1 Purpose

Homes NSW commissioned Good Environmental Choice Australia (GECA) to undertake an independent assessment of recycled content opportunities within modular housing delivered under the Modern Methods of Construction Program. The study focuses on a completed volumetric modular dwelling supplied by MOOV Modular and establishes an evidence-based approach for understanding, verifying and improving recycled content across the dwelling supply chain.

The assessment supports the implementation of the New South Wales Government's circular procurement initiatives by establishing a verified recycled content baseline, identifying priority material streams and supply chain opportunities, and providing practical recommendations to strengthen future procurement, reporting and supplier engagement. The methodology has been designed to align with recognised industry frameworks, including AS/NZS ISO 14021 - Environmental labels and declarations, the National Framework for Recycled Content Traceability and the New South Wales Recycled Content Reporting Guide, while providing a scalable approach that can be applied across future modular housing projects.

1.2 Key Findings

This report presents the completed findings of all five activities of this Recycled Content Verification Study: the literature review, supply chain mapping, opportunity analysis, recycled-content baseline and benchmark assessment, and embodied carbon assessment. Together, these activities move Homes NSW from an unverified starting position to a defensible, material-specific evidence base, with a clear set of recommendations for how that evidence base should be used and extended.

The literature review examined more than 100 publications, government policies, standards, industry reports and case studies from Australia and ten leading international jurisdictions, including the United Kingdom, Sweden, Germany, France, Canada, the United States, New Zealand, Singapore, Japan and China.

Although the policy approaches differ between countries, a clear direction has emerged internationally. Governments are increasingly combining industrialised construction with circular economy policies, requiring greater transparency of material provenance, higher recycled content, lower embodied carbon and improved building adaptability.

Several international examples demonstrate the pace of this transition:

- **New Zealand** has significantly expanded modular housing for affordable and resilient construction through Kāinga Ora, with growing emphasis on standardised procurement and circular design.
- **The United Kingdom** has invested heavily in Modern Methods of Construction (MMC), with Homes England supporting the delivery of thousands of volumetric modular social housing dwellings and integrating circular economy principles into public procurement.
- **North America** has developed a multi-billion-dollar modular housing industry led by manufacturers such as ATCO and Champion Homes, although recycled content requirements remain largely voluntary through green building certification schemes.
- **Japan** continues to demonstrate world-leading modular manufacturing through companies such as Sekisui House, combining precision manufacturing with long-life building design, component reuse and material recovery.
- **Singapore** has made Prefabricated Prefinished Volumetric Construction (PPVC) mandatory for many public developments, driving high levels of factory standardisation, material efficiency and construction quality.
- **China** continues to industrialise construction at unprecedented scale, with a documented national target of 30% of all new buildings to be prefabricated by 2025, alongside broader green building initiatives.

Across these markets, several common characteristics consistently emerged, including stronger government procurement requirements, digital material traceability, design for disassembly, increased use of recycled-content materials, embodied carbon reporting and greater reliance on Environmental Product Declarations (EPDs) and product-level verification.

Supply chain mapping identified a strong foundation for future verification

The project assessed a completed MOOV modular dwelling comprising approximately 58 m^2 of internal floor area (77 m^2 total) and developed a supply chain map for the project. Information was collected from bills of quantities, architectural documentation, supplier technical documentation, Environmental Product Declarations, recycled content declarations, technical data sheets and other supporting evidence.

To date, the project has identified more than 20 major material categories and established engagement with the principal manufacturers and distributors responsible for the majority of the dwelling's material inputs. Supplier information continues to be received and reviewed as part of the ongoing verification process.

The assessment indicates that the overall quality of supplier engagement has been positive, with most major suppliers providing technical documentation or environmental information. However, significant variation remains in the maturity of recycled content reporting between suppliers.

While many manufacturers now publish Environmental Product Declarations or sustainability documentation, these documents frequently do not provide sufficient evidence to independently verify recycled content in accordance with AS/NZS ISO 14021.

A small number of material categories represent the greatest opportunity

The preliminary hotspot assessment demonstrates that recycled content opportunities are concentrated within a relatively small number of material categories that account for most of the dwelling's material mass and procurement value.

The highest priority material streams identified include:

- Structural steel framing and fabricated steel products
- Plasterboard systems
- Insulation products
- Engineered timber products
- Aluminium window and door systems

These materials combine relatively high material volumes with high potential to establish or utilise recycled-content technologies within the Australian market, making them the most suitable candidates for future procurement improvement.

The assessment also identified additional opportunities across composite decking, vinyl flooring and selected internal finishes. While these products generally represent smaller material quantities, they may collectively contribute meaningful improvements once robust supplier verification processes are established.

An important finding is that procurement leverage is concentrated among a relatively small number of manufacturers supplying multiple product categories. Consequently, targeted engagement with a limited number of strategic suppliers has the potential to achieve significantly greater recycled content outcomes than pursuing individual product substitutions across the broader supply chain.

Australia is well positioned but further work is required

The review confirms that Australia has established many of the building blocks required to support circular modular construction, including increasing availability of recycled-content building products, Environmental Product Declarations, evolving embodied carbon initiatives and emerging government procurement policies. However, compared with international leaders, Australia continues to lag in several areas, including nationally consistent recycled content verification, digital material traceability, material passport systems and mandatory embodied carbon reporting.

A verified baseline and benchmark targets have now been established

Building on this foundation, the project has established a verified dwelling-level recycled-content baseline of 20.1 %, supported by a confidence scoring that distinguishes product-specific supplier data from manufacturing-line or site-wide averages. Benchmarking each priority material against international best practice found the gap between current performance and what is achievable varies considerably: aluminium and plasterboard show the largest gaps, composite decking and insulation already perform close to world-leading levels, and structural steel and engineered wood sit in between, constrained more by production route and market maturity than by any lack of technical opportunity. These findings form the basis of the material-specific procurement targets set out later in this report.

Embodied carbon and recycled content are related, but not interchangeable

A companion embodied carbon assessment found the dwelling's upfront carbon footprint to be 382.3 $kgCO_2e/m^2$ (A1–A3), a result consistent with published Australian and international benchmarks for a small-format, steel-framed modular home. Scenario modelling shows that increasing recycled content across the six priority materials could reduce this figure by up to 10 %, though the materials driving the greatest carbon reduction, aluminium in particular, are not always the same materials driving the greatest recycled-content gap. Structural steel illustrates this most clearly: it is the single largest contributor to the dwelling's carbon footprint, yet the carbon benefit of higher recycled content within conventional steelmaking is modest compared with the larger reduction available through a shift to electric arc furnace production.

Recommendations focus on evidence, verification and staged uplift

The recommendations arising from this study call for recycled-content and carbon evidence requirements to be built into procurement from the outset, for Homes NSW to track both a recycled-content figure and an accompanying verification-confidence score, and for third-party assurance to be phased in by material maturity. Procurement policy should also schedule future increases in minimum requirements over time to drive changes by manufacturers, and the more agencies and jurisdictions that collaborate on consistent requirements, the more likely industry will invest to meet them.

Table 1.1 summarises all sixteen recommendations arising from this study, grouped by theme and indicative implementation timeframe.

Table 1.1 *Summary of Recommendations by Theme and Implementation Timeframe*

#	Recommendation	Timeframe
Circular Design and Construction		
1	Design for disassembly from concept stage	Immediate
2	Standardise module dimensions and component interfaces	Short-term
3	Design for adaptability and multiple future uses	Short-term
Procurement and Market Leverage		
4	Build evidence and verification requirements into procurement up front	Immediate
5	Extend this assessment across the remaining panel, using MOOV as the benchmark	Short–Medium-term
6	Prioritise a small number of strategic, high-volume suppliers	Immediate
7	Specify recycled content and carbon requirements at tender stage	Short-term
Verification and Traceability		
8	Track two KPIs: recycled content and verification confidence	Immediate
9	Require third-party verified evidence, phased by material maturity	Short–Medium-term
10	Disclose product-specific vs manufacturing-average claims separately	Immediate
Material-Specific Targets		
11	Set recycled-content ceilings by material, not one blanket target	Immediate
Embodied Carbon		
12	Prioritise aluminium and steel production route as carbon levers	Short–Medium-term
13	Expect recycled content and carbon reduction to diverge by material	Immediate
Policy, Standards and Industry Engagement		
14	Calibrate supplier engagement to each material's specific constraint	Short-term
15	Support national policy and standards development	Medium–Long-term
16	Prioritise local provenance alongside recycled content as an evaluation criterion	Medium-term

Recommended Follow-up Activities

This report highlights the value in extending this type of independent, third-party assessment across the remaining supplier panel, using the MOOV baseline as a reference point. Doing so would allow this project to become the starting point for a longitudinal performance record across the Homes NSW Modern Methods of Construction Program, rather than a one-off exercise. It would also create opportunities for performance improvement: where multiple modular suppliers source from common upstream material suppliers, this knowledge would provide Homes NSW with greater leverage in pushing for improvements at source; where suppliers vary in their sourcing and manufacturing processes, best practices could be identified and shared across the panel to uplift performance across all suppliers.

The source-provenance data available for the recycled content in this study were not sufficiently robust to support conclusions about the extent to which a program of this kind is diverting waste materials from landfill. However, given NSW's strong policy interest in both waste diversion and support for local manufacturing, it would be worthwhile exploring a follow-up study that works with suppliers to verify the source of recycled content within their supply chains. This would establish the conditions needed to report a verified diversion-from-landfill outcome, and to demonstrate support for local recycling facilities.

2 Project Overview

2.1 Project Context

Homes NSW is delivering one of Australia's largest social housing programs and is increasingly adopting Modern Methods of Construction to accelerate housing delivery while improving quality, productivity and sustainability outcomes. As part of this program, MOOV Modular has been engaged to deliver permanent volumetric modular dwellings manufactured in controlled factory environments before transportation and installation on site.

At the same time, recycled content is becoming an increasingly important component of government procurement. New South Wales Government policies are placing greater emphasis on the use of recycled materials, transparent reporting and independent verification to support circular economy outcomes, reduce reliance on virgin resources and strengthen domestic recycling markets. These evolving requirements create a need for consistent methodologies that enable recycled content claims to be verified and compared across projects and suppliers.

In response, Homes NSW commissioned GECA to undertake an independent recycled content verification study for a completed MOOV modular dwelling. The project complements broader circular economy work being undertaken for Homes NSW by providing supplier-level evidence, material-specific analysis and practical recommendations that can support future procurement decisions and reporting obligations. The study has been developed as a pilot project, with the intention that the methodology can be progressively expanded across future modular housing suppliers and projects.

2.2 Objectives of the Study

The objective was to support Homes NSW in building a credible evidence base for recycled content in its modular housing supply pipeline. The project comprised six key activities, including a targeted literature review, supplier data collection and verification, and an assessment of recycled content within a completed MOOV modular dwelling.

GECA's proposed work verified recycled content data for key products within a completed MOOV modular dwelling, established a recycled content baseline, identified supply chain hotspots and data gaps, and provided practical recommendations to improve recycled content use, reporting readiness, and alignment with NSW Government circular procurement requirements.

The project activities were structured as follows:

- **Activity 1 – Literature Review:**

Reviewed priority literature available globally that highlights good practice and opportunities for measuring and increasing recycled content within modular housing.

- **Activity 2 – Data Collection and Assessment:**

Conducted a targeted review of existing project documentation, design information, and available data to establish the baseline scope and identify initial data gaps. Gathered detailed supplier documentation and evidence and undertook initial assessment of recycled content claims and associated product data, with data collection and opportunity analysis treated as ongoing activities that will continue to inform future work and be updated as new data becomes available.

- **Activity 3 – Opportunity Analysis:**

Analysed collected data to identify opportunities to increase verified recycled content and improve data transparency across materials and suppliers.

- **Activity 4 – Baseline and Benchmark Targets:**

Established a baseline for recycled content within the MOOV modular dwelling and define benchmark targets aligned with project and industry expectations. Provided, where possible in collaboration with Rebuilt, an indicative assessment of the impact of increasing recycled content on the upfront embodied carbon of priority materials.

- **Activity 5 – Data Evaluation:**

Evaluated the quality, consistency, and reliability of collected data, including assessment of recycled content verification status and identification of residual data gaps or risks.

- **Activity 6 – Recommendations:**

Provided targeted, actionable recommendations to improve recycled content outcomes, strengthen data quality, and support ongoing supplier engagement and reporting.

GECA worked collaboratively with Homes NSW, MOOV, and relevant suppliers to collect and review supporting documentation, including bills of materials, product specifications, supplier declarations, certifications, Environmental Product Declarations (EPDs), product carbon data, and other relevant evidence. This information was used to identify both verified and self-declared recycled content claims, assess data quality and completeness, confirm material provenance, and highlight gaps requiring supplier follow-up.

GECA then analysed the supply chain to identify material hotspots and opportunities to increase recycled content, establish a verified recycled content baseline and indicative benchmark targets, and, where possible, assess upfront embodied carbon impact of increasing recycled content. The final output is a verified baseline report with practical recommendations for design, specification, procurement, supplier engagement, verification and reporting, helping Homes NSW meet circular procurement and recycled content reporting requirements.

Assessment Boundary

The assessment boundary for this study is limited to the materials and products incorporated within the completed MOOV volumetric modular dwelling and associated building elements, as documented in the project Bill of Quantities and supplier data. This includes the external decking system, which forms part of the modular package supplied with the dwelling. The assessment focuses on the modular building package and excludes site-specific works and infrastructure unless explicitly captured within the assessed project documentation. Excluded elements may include, where applicable, foundation and site-preparation works including any concrete associated with the screw-pier system, landscaping, external infrastructure, separately installed building services (such as HVAC and hot-water systems), solar installations, driveways, and other post-installation works that fall outside the modular construction scope.

3 Literature Review and Industry Analysis: Circular Modular Housing

This literature review forms the initial phase of a broader project to advance circular economy principles and recycled content integration into affordable modular housing for Homes NSW. The purpose of this desktop review is to capture and synthesise global best practice in relation to the integration of circular economy principles and practices into modular construction, and to then apply those lessons in the Homes NSW context. The findings will guide and inform subsequent project activities (**Activities 2 to 6**) by highlighting what is achievable worldwide and identifying key opportunities and challenges for New South Wales (NSW). Ultimately, this work supports Homes NSW's strategic objectives to deliver more sustainable, circular, resource-efficient and affordable social housing, and to align with NSW Government policies on waste and greenhouse gas (GHG) emissions reduction and increasing the use of recycled materials in modular homes.

The baseline reference for this study is a MOOV Modular volumetric dwelling (**Figure 3.1**). This single-storey dwelling unit, constructed in steel-framed modules and finished on a lightweight foundation, represents typical current practice and will be used to compare against the circular strategies identified. The baseline currently uses mainly conventional materials (steel frame, plasterboard, fibre-cement and timber cladding, vinyl flooring, and standard fixtures and finishes – see **Appendix D**) with only incidental recycled content (e.g., standard steel has around 10–30% recycled steel scrap input). Its design does not yet explicitly incorporate design-for-disassembly approaches or material passports. This baseline will be referenced throughout the analysis to contextualise opportunities for improvement. **Figure 3.1** also illustrates key construction stages and representative building elements observed during fabrication and completion of the dwelling.

3.1 Literature Review Methodology

The review methodology maintained a systems perspective throughout to evaluate how policy, procurement, design, manufacturing, materials and supply chain collaboration all interact to enable circular outcomes in modular housing. This approach recognises that circularity cannot be achieved through isolated interventions alone. Effective implementation of circular economy principles and practices, including the integration of recycled materials, requires coordination across all stages of a building's lifecycle, including eventual deconstruction, repurposing, reuse and recycling of materials and building components.

The literature review primarily focused on nine countries/regions known for leadership in either modular construction or circular economy thinking in buildings (or both): the United Kingdom, Sweden, Germany, France, United States, Canada, New Zealand, Japan and China, with supplementary references to Singapore and Portugal where relevant.

These regions exemplify a range of market conditions – from Europe's strong circular economy policies and high modular uptake to North America's industry-driven initiatives, to Asia's technological and regulatory advances, to New Zealand's similar context to Australia's (a small market adopting modular construction to meet its housing needs).





Figure 3.1 *Pilot Baseline and representative building elements of MOOV modular volumetric dwelling*

Figure 3.2 below summarises the different markets for modular housing and the approaches and enablers in these markets, as well as the presence of forward-thinking circular economy policies and practices.

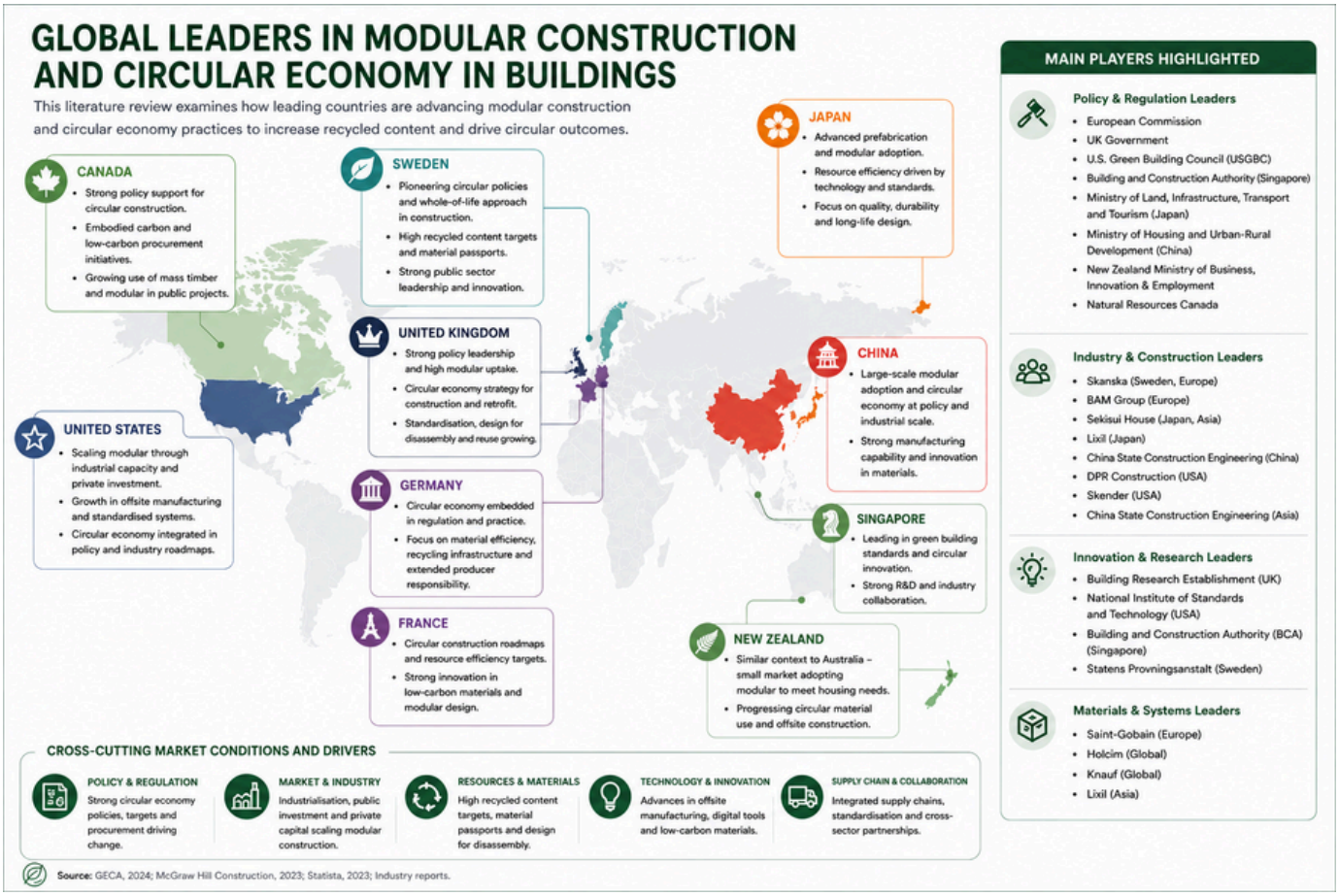


Figure 3.2 *Global leaders in modular construction and circular economy policy*

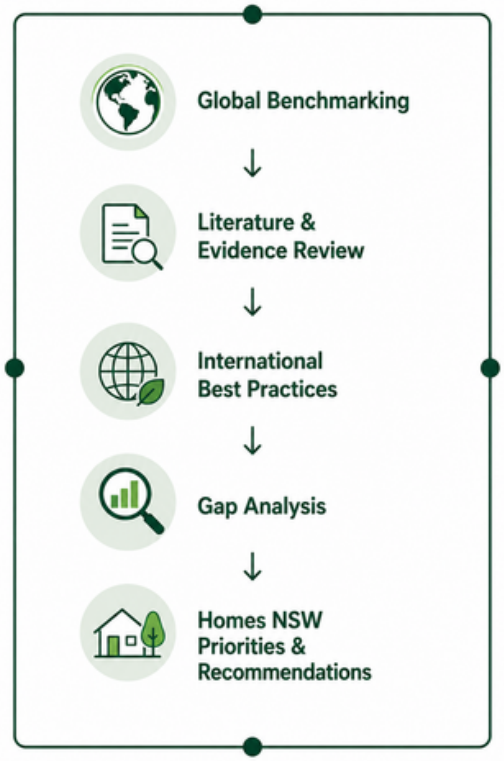
A key focus of the review was to identify and describe the intersection of circular economy principles and practices, and recycled content integration in modular or prefabricated construction as an important component of delivering circularity in the target geographies above and how they can be applied in the Australian context.

In practice, this meant that the review gathered information on topics such as design for disassembly and longevity, adaptable building design, the repurposing and reuse of materials in new construction projects, the use of high recycled content materials, embodied carbon and closed-loop supply chains – specifically as they relate to modular housing and particularly volumetric modular building.

While this review highlights the relationship between circular economy strategies, the benefits of repurposing, reusing and recycling building materials, products and components, and the use of recycled content in projects to reduce embodied carbon, a more detailed, quantitative analysis of embodied carbon benefits falls outside the scope of this report.

The research was structured in five main stages:

- **Global Benchmarking:** Identifying leading countries and markets, jurisdictions and organisations demonstrating circular economy practices in modular construction, to set the context for analysis.
- **Literature & Evidence Review:** Collecting and reviewing a broad range of sources (peer-reviewed research, government publications, industry reports, international standards, case study documentation) to gather evidence of best practices and track record.
- **Comparative Assessment:** Evaluating each jurisdiction against common criteria, including maturity of circular design practices, extent of recycled content integration, material traceability, policy support, and industrial capability.
- **Gap Analysis:** Comparing international practices against current Australian conditions and Homes NSW's objectives, to identify areas where NSW lags or leads.
- **Strategic Recommendation:** Synthesised findings to identify opportunities, barriers and enabling factors relevant to NSW's modular housing program.



During this review emphasis is placed on recent (2018–2025) evidence and sources with quantitative data on outcomes (e.g., measured waste reduction, recycled content percentages, lifecycle impacts). However, emerging frameworks and conceptual papers were also included to illustrate the future direction of "circular construction", though full-scale real-world examples remain limited. Sources were critically appraised for credibility, prioritising official publications (government, standards bodies, international agencies) and peer-reviewed studies, with industry publications and media reports used only where they provide unique insights or case study examples (and are corroborated where possible).

Financial considerations were implicitly considered by focusing the research on low-cost projects, given that the Homes NSW project relates to affordable social housing. However, this cost analysis is only discussed qualitatively as a detailed cost–benefit analysis falls outside the scope of the literature review.

The review additionally examined policy frameworks and standards that encourage these practices. Australia's present state is considered later in **Section 3.4**, to highlight local gaps relative to global leaders.

3.2 Global Trends and Case Studies

3.2.1 Circular economy strategies, principles and practices

Global construction is undergoing a twin transformation: increasing the adoption of industrialised modular construction and making a strategic shift toward circular economy principles and practices. Together these trends encourage circular modular construction, combining the quality and speed of factory-built housing with design strategies to reduce resource consumption, greenhouse gas emissions and waste.

A circular economy approach means shifting away from a linear 'take, make, use and dispose' approach to one that better values resources. This means using materials efficiently and keeping products and materials in use for as long as possible. We can do this by reducing the use of materials, designing out waste from the outset and using materials and products that are repairable, re-usable and recyclable. At the end of their life, assemblies or components can also be repurposed, reused and recycled at their highest value and utility.

There are a number of key principles that help to inform circular design and construction strategies. One commonly used set of principles is the '9Rs', which describes the hierarchy of strategies that should be applied to materials, products, businesses and systems in the shift towards a circular economy. The hierarchy proposes refusal of material use and consumption as the highest priority, before moving to actions that extend the useful life of a product during its use stage. Recycling and recovery are the lowest priority circular strategies. Within the 9Rs framework, reuse is a higher priority scenario than recycling. This hierarchy is reflected in ISO 59020:2024 *Circular economy — Measuring and assessing circularity performance*, which defines reused content as: 'A component or part that has reached the end of one use and is used again with minimal or no physical alterations'. **Figure 3.3** summarises the 9Rs framework.

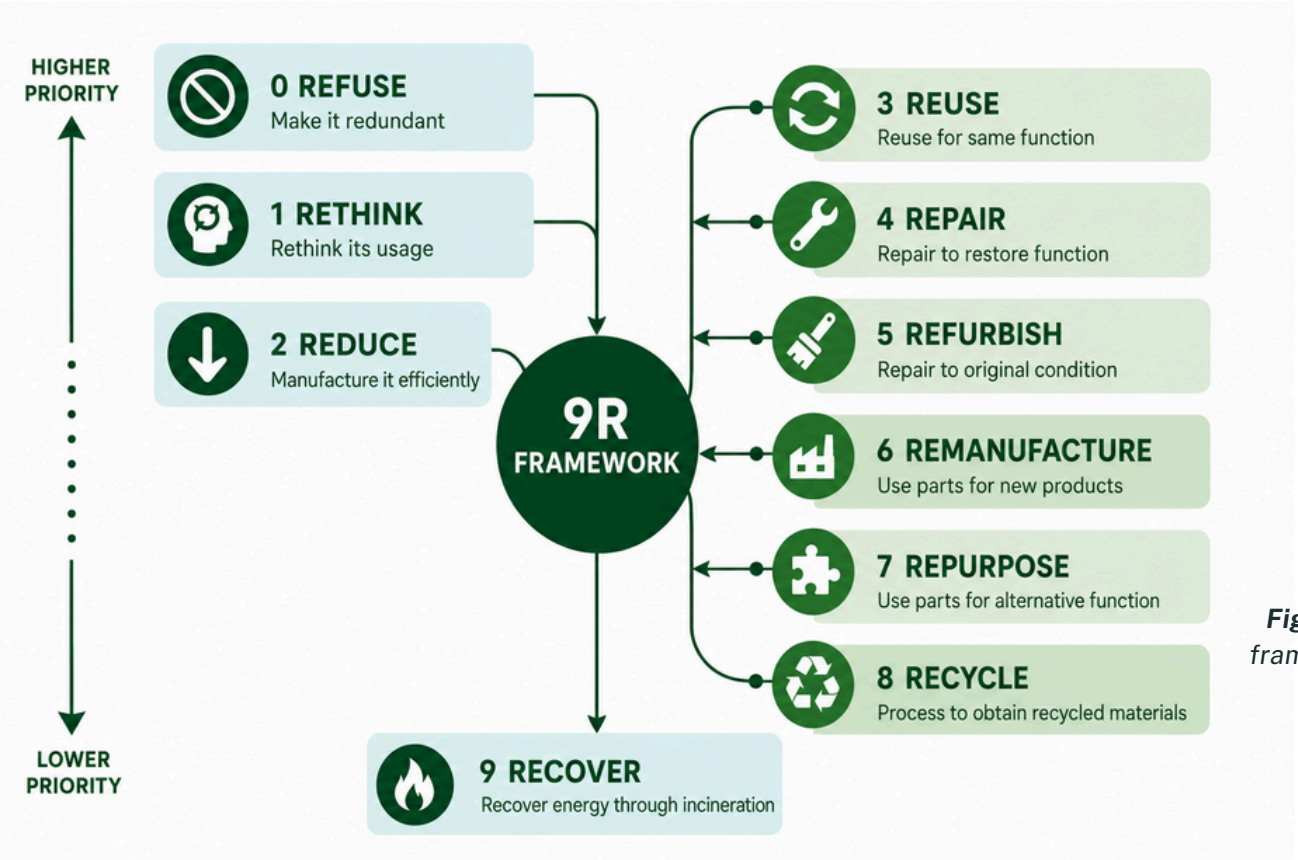


***Figure 3.3** The 9Rs framework (Sources: NSW Bradfield Development Authority, 2025)*

Globally, the building sector produces enormous environmental impacts – accounting for an estimated 37% of energy-related global greenhouse gas (GHG) emissions and over one third of global raw material consumption. Construction and demolition waste exceeds 2.2 billion tonnes annually worldwide, putting pressure on landfills and resource supplies. In response, governments and industry leaders are pursuing new approaches to deliver buildings faster and more sustainably (UNEP, 2026).

In Australia, the construction industry represents 9% of national industrial output ($177 billion in 2023-2024), and is a major consumer of materials, accounting for 42% of all non-metallic materials and 25% of all metallic minerals (Productivity Commission, 2025).

The sector is still predominantly operating using linear economy 'take-make-use-dispose' thinking, generating 29Mt of construction and demolition (C&D) waste a year (costing the Australian economy over $2 billion a year) (Senaratne, S. et al, 2025), 39% of all the waste generated in Australia, with over a quarter (26%) of this waste going to landfill. Construction processes and associated manufacturing activities account for 2% and 8.4% of Australia's greenhouse gas emissions respectively. With over $270 billion of publicly funded infrastructure projects alone forecast over the next four years, there are huge opportunities for the public sector to drive better circularity and climate outcomes through project procurement and contractual requirements and supplier engagement (Productivity Commission, 2025).

The role of modular construction methods in delivering better economic, sustainability and circularity outcomes

Volumetric modular construction (factory-produced building modules assembled on site – see **Figure 3.4**) has emerged as one of the most advanced and modern construction methods, offering opportunities to embrace circular economy principles and improve sustainability outcomes, that can be harder to achieve with conventional building methods, including:

- **Improved material utilisation and reduced waste:** precision manufacturing means fewer offcuts and errors, with factories achieving very low waste-to-landfill (some reporting 5-15 kg waste per square metre, versus 40–50 kg in traditional builds) (Sustainability Atlas, 2026).

- **Enhanced quality control and productivity**: repetition and automation improve consistency, reduce defects, and increase building speed (McKinsey and Company, 2020).

- **Enhanced worker safety and reduced construction costs and project timelines:** factory settings minimise on-site risks and, according to international studies, typical modular projects complete up to 20–50% faster than conventional construction; and can reduce construction costs by up to 20% (Senaratne, S. et al, 2025). Productivity Commission modelling suggests that if these types of productivity improvements were realised in Australia it could increase GDP by $2.9-$5.7 billion (Productivity Commission, 2025).

- **Traceability and recycled content integration and verification:** using reclaimed or recycled materials in new building components in a controlled factory environment, where they can be clearly labelled and documented, simplifying the verification of recycled content. For example, leading modular social housing projects in the Netherlands, including Appelweg and Brasa Village, use digital material passports and material profiles to record component provenance, recycled content, maintenance history and reuse potential, improving transparency and supporting future circular-economy outcomes (Appelweg and Project OPZuid, 2026).

- **Design for Disassembly (DfD):** ensuring that building components can be easily separated for reuse or recycling – has emerged as a key strategy to extend building lifespans and divert future waste from landfill.

- The use of a wider range of innovative recycled and bio-based building materials as technologies improve and the cost of virgin material extraction rises (e.g., structural steel made from scrap, recycled aggregate in concrete products, mycelium-based insulation panels) offers new avenues to reduce embodied carbon and waste.



Figure 3.4 *Different types of modular construction*

Major markets around the world are illustrating these trends in practice:

New Zealand, for example, has rapidly expanded modular housing for affordable and seismic-resilient construction, with *Kāinga Ora* (the government housing agency) delivering large social housing projects using prefabrication.

The **United Kingdom** has likewise invested strongly in Modern Methods of Construction (MMC), deploying thousands of new volumetric social homes via Homes England and industry partners.

In **North America**, modular construction has scaled to a multi-billion-dollar sector aided by strong housing demand, with key players like ATCO and Champion Homes delivering high volumes. In the U.S., modular housing is increasingly embraced in disaster relief and affordable housing programs (though formal recycled content requirements remain limited to voluntary green building certifications).

Japan has one of the most mature modular industries globally – major firms like Sekisui House have produced prefabricated housing for decades – characterised by precision manufacturing, automation and exceptional quality; recent efforts in Japan have added circular practices, such as material recycling and designing homes for longer lifespans.

Singapore has made Prefabricated Prefinished Volumetric Construction (PPVC) mandatory for many public projects, driving advanced modular production with strong waste minimisation and resource efficiency outcomes.

China, the world's largest construction market, is deploying prefabrication at massive scale under state industrialisation policies and "green building" initiatives – for example, China's Ministry of Housing and Urban-Rural Development has set targets for 30% of all new buildings to be prefabricated by 2025.

This initial literature review identified a number of country case studies where different strategies and practices have been deployed to implement circular economy thinking in factory prefabricated modular housing. Examples are included below.

Design for disassembly and reuse

Design for Disassembly (DfD) emerged as one of the most consistently applied circular economy strategies across the international case studies reviewed. DfD enables buildings and components to be dismantled without damage, allowing modules, structural elements and materials to be reused, refurbished or relocated at the end of their initial service life. International Standards, like ISO 20887:2020 - Design for disassembly and adaptability in buildings, also provide practical guidance for those involved in the built environment.

The Reusable Modular Mass Timber (RMMT) system developed in Japan is a good example of a modular building system that is designed for disassembly. The RMMT system utilises screw-fixed cross-laminated timber (CLT) panels and structural insulated panels (SIPs) designed for repeated assembly and disassembly. **Figure 3.5** below illustrates the Japanese RMMT approach to modular housing.

Lifecycle modelling of the Japanese RMMT demonstrated that up to 90% of building components could be recovered and reused during subsequent building cycles, substantially reducing embodied carbon impacts over a 60-year assessment period.



Figure 3.5 *Reusable Modular Mass Timber (RMMT) case study (Japan) (Source: Passarelli, R.N., 2019)*

Modular standardisation and interchangeability

Standardisation was identified as a critical enabler of circularity, scalability and cost efficiency across the modular housing sector. Standardised module dimensions, component interfaces and manufacturing processes facilitate easier replacement, refurbishment, relocation and reuse of building elements throughout their lifecycle.

The strongest examples were observed in industrialised modular housing systems operating at scale. Sweden's BoKlok housing platform (**Figure 3.6**) has delivered more than 13,000 homes using highly standardised timber volumetric modules and repeatable design configurations. This approach has enabled efficient factory production, reduced material waste and simplified future maintenance and refurbishment activities (BoKlok, n.d.).



Figure 3.6 *Sweden's BoKlok prefabricated housing. Photograph: BoKlok*

China's HOLON Building system developed by BROAD Group (**Figure 3.7**) represents a highly industrialised approach to standardisation. The project utilised factory-manufactured stainless-steel modules based on a common structural platform that enabled rapid assembly of 56 modules into an 11-storey building within 29 hours. The system incorporates standardised structural and service interfaces, allowing flexibility in building configuration while maintaining manufacturing efficiency (BROAD Group, n.d.).



Figure 3.7 *BROAD Group's Holon stainless steel modular building*

Similarly, Japanese prefabricated housing manufacturers such as Sekisui House have developed highly standardised component systems that support mass customisation while maintaining compatibility between building elements (**Figure 3.8**). These approaches enable component replacement and future upgrading without requiring complete building replacement (Sekisui House, n.d.).

From a circular economy perspective, standardisation creates opportunities for establishing secondary markets for modular components and facilitates future reuse across multiple projects. The evidence suggests that developing a standardised modular platform for social and affordable housing could significantly improve circular outcomes while supporting procurement efficiencies and long-term asset management objectives.





Figure 3.8 *Sekisui House Japanese prefabricated housing (Source: Sekisui House, n.d.)*

Designing buildings for adaptability and multiple future uses

Adaptability is a key circular design principle that extends building service life by enabling structures to accommodate changing user requirements, demographic shifts and evolving functional needs. Unlike traditional buildings designed for a single purpose, adaptable modular buildings can be reconfigured, expanded, relocated or repurposed with minimal material loss.
Many of the case studies demonstrated high levels of adaptability. The Japanese RMMT concept incorporates a modular kit-of-parts approach allowing buildings to be expanded, reduced or relocated depending on changing household requirements.

The strongest examples of adaptability were found within the UK modular refurbishment sector. Modular units originally designed as schools, offices or temporary accommodation have subsequently been relocated and repurposed for alternative uses, including residential accommodation and community facilities. Bradfields Academy (Premier Modular, n.d.), for example, utilised refurbished modules that had previously served multiple educational facilities, demonstrating how modular assets can remain in productive use across several locations and applications.

Scandinavian housing systems, such as BoKlok (BoKlok, n.d.), also incorporate flexibility through repeatable layouts, interchangeable components and scalable building configurations. These features enable housing developments to evolve over time while maintaining the integrity of the original structural system.

The evidence suggests that adaptability provides significant value for social and affordable housing providers by reducing future refurbishment costs, extending asset life and improving resilience to changing housing demand. For Homes NSW, adaptable modular housing could support future reconfiguration of dwelling types, accessibility upgrades and site redevelopment without requiring complete building replacement.

Integration of digital platforms for material traceability

Digital technologies are increasingly recognised as critical enablers of circular construction. Material traceability systems provide information about the composition, location, performance and future reuse potential of building materials and components throughout their lifecycle(s).

Internationally, the most advanced examples are emerging in Europe, where material passport platforms and digital building logbooks and manuals are being integrated into circular construction initiatives. These systems create a digital record of materials embedded within buildings, allowing future owners and contractors to identify reusable components and recover value at end-of-life.

Several modular housing case studies demonstrated early adoption of digital traceability principles. The HOLON Building system integrates advanced digital manufacturing, quality assurance and asset management processes, enabling detailed tracking of building components from factory production through to operation. The highly standardised nature of the system also facilitates future identification and replacement of components (BROAD Group, n.d.).

Similarly, emerging material passport initiatives associated with design-for-disassembly projects in Northern Europe are providing digital inventories of structural components, connection systems and material specifications. These platforms support circular procurement, facilitate future reuse and reduce uncertainty regarding material quality and provenance.

Digital traceability also has the potential to support the use of recycled materials and lifecycle carbon accounting. By linking component data with environmental product declarations (EPDs) and other verified sources of data, building information modelling (BIM) systems and material passports, housing providers can monitor embodied carbon, recycled content and material recovery performance throughout the asset lifecycle.

Designing for durability and improving operational performance, resource and energy efficiency

A consistent finding across the case studies was that circular modular housing strategies frequently deliver improved durability and operational performance alongside material efficiency benefits.

Several projects demonstrated exceptional durability outcomes. The HOLON Building system utilises stainless-steel structural framing designed for a service life reportedly up to twenty times longer than conventional reinforced concrete systems, while maintaining a material recovery rate exceeding 98%. Similarly, volumetric modular systems in Japan have been developed to meet stringent seismic performance requirements, resulting in highly durable and adaptable housing assets.

Operational energy performance was also a common strength. HOLON reports operational energy consumption reductions of approximately 80–90% compared with conventional buildings through high-performance building envelopes, energy recovery ventilation systems, advanced controls and enhanced airtightness. New Zealand's modular social housing projects certified under Homestar standards similarly demonstrated strong thermal performance and reduced operational energy demand.

Sweden's BoKlok housing platform combines factory precision, timber construction and high-performance insulation systems to achieve significant reductions in operational energy consumption while maintaining affordability. The use of engineered timber systems additionally contributes to lower embodied carbon compared with conventional concrete construction.

Factory-based construction methods consistently reduced material waste generation. Multiple case studies reported waste diversion rates approaching 90%, while the HOLON system reported less than 1% construction waste sent to landfill. Refurbished modular systems operated by Premier Modular and Wernick achieved near-complete material recovery through refurbishment and reuse processes, avoiding the need for new material production.

Additional resource efficiency benefits observed across the case studies included:

- Reduced waste through precision manufacturing and digital fabrication technologies.
- Improved material utilisation through standardised module designs.
- Greater opportunities for offcut recovery and reintegration into production processes.
- Enhanced quality control and product consistency.
- Increased ability to trial innovative recycled-content materials.
- Reduced damage to materials during storage, transport and installation.

The combined evidence suggests that modular housing can simultaneously deliver circularity, durability and operational efficiency benefits when supported by integrated design, manufacturing and asset management strategies. These outcomes are particularly relevant for Homes NSW, where long-term asset performance, operating costs and environmental outcomes are critical considerations alongside housing delivery objectives.

Whole-of-life and beyond first life thinking

Taking a whole-of-life perspective ensures that project performance is evaluated across the entire building lifecycle rather than being limited to construction-stage outcomes. This approach recognises that many of the environmental benefits associated with circular modular housing are realised through extended asset life, material reuse, refurbishment and end-of-life recovery – all of which drive better circularity, resource and energy efficiency and associated GHG emissions outcomes.

Modular prefabricated construction of homes allows for the upfront assessment of the embodied carbon and resource consumption based on the selection and use of known materials and precision manufacturing techniques. Case studies illustrated that it is possible to determine how alternative material choices, such as recycled steel, reclaimed timber, recycled aggregates, mass timber systems and low-carbon construction products, can influence the overall environmental performance of modular housing.

This makes it easier to make informed decisions about the use of materials that have lower embodied carbon and higher recycled content, particularly when backed up by Life Cycle Assessment (LCA) data, where it is available, and to compare circular modular solutions against conventional construction approaches. For example, timber-based modular systems in Sweden and Japan achieved lower embodied carbon through the substitution of carbon-intensive materials.

A whole-of-life approach also allows for the evaluation of how projects address end-of-life outcomes and future material recovery and reuse by incorporating Design for Disassembly (DfD), modular kit-of-parts approaches and reversible connection systems that enable buildings to be dismantled without damaging components. Case study examples, such as the Reusable Modular Mass Timber (RMMT) system in Japan and refurbished modular building programs in the United Kingdom, illustrate how modular housing can be designed to support multiple use cycles rather than a single linear lifecycle. These projects demonstrate that substantial proportions of building materials can be retained at the end of a building's initial service life and redeployed in future developments.

Beyond consideration of individual materials, case studies from other countries show that it is possible to consider broader material flow dynamics within a multi-use/life circular economy context. This includes assessing whether projects create pathways for materials to remain in productive use through refurbishment, remanufacturing, relocation or reuse. Several case studies demonstrated circular business models that move beyond traditional ownership structures. The Japanese RMMT concept, for example, explored product-service system approaches in which building modules could be leased, recovered and redeployed, while modular refurbishment programs operated by UK manufacturers effectively function as closed-loop systems by returning modules to factory environments for upgrading and reissue. These models preserve the value embedded in materials and components while reducing demand for virgin resources.

Where quantitative information was available in international case studies, material flow outcomes were able to be benchmarked using measurable indicators. These included reductions in virgin material consumption, percentages of reused or recycled content, construction and demolition waste diversion rates, material recovery rates and embodied carbon savings. Several leading examples reported exceptionally strong performance. The HOLON Building system reported material recovery rates exceeding 98% and less than 1% construction waste sent to landfill, while factory-based modular housing systems commonly reported waste reductions of up to 90% compared with traditional construction methods. Refurbished modular systems in the UK achieved near-complete recovery of structural components, significantly extending asset life while avoiding the environmental impacts associated with new material production.

Adopting a whole-of-life perspective and using a material flow lens enables a more sophisticated assessment of circularity beyond the first life of a building. It distinguishes projects that simply incorporate recycled content from those that fundamentally redesign how materials are sourced, used, recovered and recirculated throughout the building lifecycle. As a result, it is possible to identify not only current best practice but emerging circular business models and material management strategies that have the greatest potential to transform the housing sector over the long term.

3.2.2 Material Innovations

Rather than focusing solely on innovative materials, the international review demonstrates that material selection is increasingly being used as a strategic mechanism to improve circularity, reduce embodied carbon and retain material value over successive building lifecycles. Across the case studies, material innovation was consistently linked with industrialised manufacturing, where factory-controlled production enabled greater consistency in product quality, reduced construction waste and more reliable integration of recycled and renewable materials.

Four broad material innovation pathways emerged across the reviewed projects: low-carbon concrete and recycled aggregates; engineered timber and reclaimed wood products; recycled plastics and composite materials; and emerging bio-based material systems. Although these technologies differ in maturity, they share a common objective of reducing reliance on virgin materials while supporting higher-value resource recovery and longer material life. Together, these findings provide the technical basis for the material hotspot assessment presented in the following chapters, where the applicability of these innovations is evaluated against the MOOV modular dwelling supply chain.

Recycled aggregates and low-carbon concrete systems

Concrete remains one of the most widely used construction materials globally and is a significant contributor to embodied carbon emissions. Consequently, substantial research and industry innovation have focused on reducing the environmental impact of concrete through the incorporation of recycled materials and alternative binders.

Several international projects demonstrated the use of recycled concrete aggregates (RCA) recovered from demolition waste and reintroduced into new construction products. European circular construction initiatives, including projects associated with the RECONSTRUCT program and broader EU circular economy pilots, have shown that recycled aggregates can be successfully incorporated into prefabricated structural and non-structural components while maintaining acceptable engineering performance.

Beyond aggregate substitution, low-carbon concrete technologies are increasingly being adopted within modular manufacturing. These include the use of supplementary cementitious materials, such as fly ash, ground granulated blast-furnace slag (GGBFS), silica fume and calcined clay to reduce Portland cement content. Such approaches can reduce embodied carbon by 20–53% depending on the mix design and replacement rates achieved (Chen, S. et al, 2023).

Modular construction offers additional advantages by enabling more efficient concrete production and reducing waste through precision manufacturing and the use of precast concrete products. Factory-based production also facilitates quality control and the consistent incorporation of recycled materials that may be more difficult to manage on traditional construction sites. While the reviewed case studies generally focused more heavily on timber and steel systems, low-carbon concrete remains highly relevant for foundations, podium structures, service corps and hybrid modular developments. Future modular housing programs in NSW could leverage increasing availability of recycled aggregates and low-carbon concrete products to reduce embodied carbon while supporting local resource recovery markets.

Reclaimed Timber and Engineered Recycled Wood Products

Timber-based construction featured prominently across many of the highest-performing circular housing case studies. Reclaimed timber and engineered wood products offer significant environmental advantages through carbon storage, reduced embodied emissions and the potential for repeated reuse across multiple building lifecycles.

Sweden's BoKlok housing platform has demonstrated the scalability of industrialised timber modular construction, delivering more than 13,000 homes using highly standardised timber-based systems. Although primarily based on sustainably sourced timber, the project illustrates the broader role of renewable and low-carbon materials within modular housing.

The Reusable Modular Mass Timber (RMMT) system in Japan represents a more advanced circular approach. The system uses cross-laminated timber (CLT) panels and structural insulated panels (SIPs) connected through reversible mechanical fixings, enabling components to be disassembled and reused at the end of each building cycle. Lifecycle modelling indicated that approximately 90% of structural materials could be retained for future use, significantly reducing long-term resource consumption and embodied carbon.

Engineered wood products such as CLT, laminated veneer lumber (LVL) and glulam are increasingly being combined with recycled timber feedstocks and recovered wood fibres. These products provide structural performance comparable to conventional materials while supporting circular material flows and long-term carbon sequestration. For NSW, engineered timber systems offer significant opportunities to combine modular construction with circular economy objectives, particularly where designs incorporate future disassembly and material recovery.

Recycled Plastics and Composite Materials in Modular Systems

The use of recycled plastics and composite materials is emerging as an important strategy for diverting waste streams from landfill while reducing demand for virgin polymer products. Modular construction is particularly suited to these materials because many components can be manufactured under controlled factory conditions and integrated into repeatable product systems.

Across the reviewed case studies, recycled plastics were most commonly used in non-structural applications including insulation products, floor coverings, wall linings, façade systems, roofing membranes, decking products and interior fit-out components. Composite materials manufactured from recycled plastics and wood fibres are increasingly being used for external cladding systems, decking products and façade elements. These materials offer durability advantages, reduced maintenance requirements and resistance to moisture degradation, making them suitable for modular applications where lifecycle performance is critical.

Several European circular construction initiatives have also explored the use of recycled polymer products manufactured from post-consumer waste streams. These products contribute to waste diversion objectives while supporting local circular economy supply chains. Although structural applications remain relatively limited, advances in recycled polymer composites and fibre-reinforced materials are expected to expand future opportunities for integrating recycled plastics into modular housing systems. As manufacturing technologies mature, recycled composites may play an increasingly important role in reducing material-related environmental impacts.

Bio-Based and Hybrid Materials

Bio-based materials represent one of the most promising areas of innovation within circular construction. Derived from renewable biological resources, these materials have the potential to significantly reduce embodied carbon while creating pathways for regenerative material cycles.

International research and demonstration projects have increasingly explored the use of agricultural waste fibres, hemp-based composites, straw panels, cellulose insulation, bamboo products and mycelium-based materials. Many of these materials utilise agricultural by-products that would otherwise be discarded or underutilised, creating additional circular economy benefits. Mycelium composites, produced by growing fungal networks around agricultural waste substrates, have attracted considerable attention as low-carbon alternatives to conventional insulation and lightweight building products. These materials require minimal processing energy and are fully biodegradable at end-of-life. While still largely in the demonstration phase, several pilot projects have successfully incorporated mycelium products into modular and prefabricated construction systems.

Agricultural waste composites, including straw-based panels, hemp-lime systems and fibre-reinforced biocomposites, have also demonstrated potential for modular housing applications. These materials can offer favourable thermal performance, reduced embodied carbon and opportunities for regional manufacturing using locally available feedstocks.

Hybrid material systems are increasingly combining bio-based materials with engineered timber, recycled steel or recycled-content products to optimise structural performance while minimising environmental impacts. Examples include timber-hybrid modular systems, bio-based insulation integrated within volumetric modules and composite panels manufactured from agricultural fibres and recycled polymers. Although most bio-based materials remain at an earlier stage of market adoption compared with timber or recycled steel systems, they represent a significant opportunity for future circular housing development. Continued advances in product certification, building code acceptance and manufacturing scalability are expected to accelerate adoption over the coming decade.

Collectively, these material innovations demonstrate that circular modular housing extends beyond construction methods alone. The most advanced international examples combine industrialised manufacturing with low-carbon, renewable and recycled material systems to reduce resource consumption, lower embodied carbon and create pathways for long-term material recovery and reuse. These approaches provide valuable insights for Homes NSW as it explores opportunities to integrate circular economy principles into future modular housing programs.

3.2.3 Recycled Content Integration Approaches

The integration of recycled materials is a fundamental component of circular modular housing and represents one of the most direct mechanisms for reducing reliance on virgin resources, lowering embodied carbon and diverting waste from landfill. Across the international case studies reviewed, recycled content was incorporated through a variety of approaches ranging from the use of recycled structural materials to closed-loop manufacturing systems and circular procurement strategies (UNEP, 2018).

Modular construction provides several advantages for recycled material integration compared with conventional construction. Factory-controlled production environments improve material quality control, enable consistent incorporation of recycled-content products, reduce waste generation and facilitate verification of material provenance. In addition, modular manufacturing allows innovative recycled products to be tested and deployed at scale with greater certainty regarding performance outcomes. The case studies demonstrated that successful recycled content integration extends beyond individual products and increasingly involves supply chain transformation, material traceability and circular business models that retain material value throughout multiple building lifecycles.

Integration of recycled materials at structural and component level

The reviewed projects demonstrated varying levels of recycled material integration, ranging from individual building components through to primary structural systems.
At the structural level, recycled steel was the most commonly adopted material due to its established recycling infrastructure, high recovery rates and compatibility with modular manufacturing. The Legacy Living Lab (Australia) incorporated reused structural steel elements and demonstrated significant reductions in lifecycle greenhouse gas emissions through component reuse. Similarly, many volumetric modular systems in the United Kingdom, Canada and Australia utilise steel-framed modules that contain substantial recycled content while maintaining structural performance and durability requirements.

Timber-based modular systems also demonstrated opportunities for integrating reclaimed and recycled wood products. Examples included the use of recycled timber products, recovered wood fibres and engineered wood components designed for multiple use cycles. The Reusable Modular Mass Timber (RMMT) system in Japan further extended this concept by enabling structural timber elements to be recovered and reused across successive building lifecycles.

At the component level, recycled materials were integrated into a broad range of products including flooring, insulation, internal finishes, façade systems, roofing materials and fit-out components. The Legacy Living Lab incorporated second-life carpet tiles and recycled timber products, while several projects utilised recycled-content insulation, composite cladding products and reclaimed interior materials.
The case studies demonstrate that the most advanced examples combine recycled content across multiple building systems rather than limiting its application to isolated products. This integrated approach maximises resource efficiency while reducing overall embodied environmental impacts.

Factory-controlled environments enabling higher material efficiency

One of the most significant advantages of modular construction is the ability to manufacture building components within controlled factory environments. This production model enables substantially greater material efficiency than traditional site-based construction and creates favourable conditions for integrating recycled materials.

Factory production allows precise material ordering, automated cutting processes and standardised assembly procedures that significantly reduce offcuts and construction waste. Numerous case studies reported waste reductions of up to 90% compared with conventional construction methods. The HOLON Building system developed by BROAD Group reported less than 1% construction waste sent to landfill and material recovery rates exceeding 98%, demonstrating the potential for near-circular manufacturing systems.

Controlled production environments also enable manufacturers to incorporate recycled materials that may be more difficult to manage on traditional construction sites. Variations in material dimensions, quality or appearance can be more effectively accommodated through factory-based quality assurance processes, allowing greater utilisation of recovered materials without compromising building performance. These advantages position modular construction as a key enabler of circular economy objectives and support higher levels of recycled content integration than are typically achieved in conventional construction.

Closed-loop supply chains and material reuse systems

The most advanced circular housing case studies extended beyond consideration of the use of recycled content across one home lifecycle, demonstrating closed-loop approaches in which materials and components are intentionally designed to remain within productive use across more than one home lifecycle.

Several UK modular manufacturers have developed refurbishment-based business models that recover existing modular buildings, return them to factory environments and reissue them for new projects. Premier Modular and Wernick provide strong examples of this approach, whereby modules are stripped back, refurbished and redeployed rather than demolished. This process preserves the embodied value of structural materials while significantly reducing demand for new resource extraction.

The HOLON Building system similarly incorporates highly recoverable materials and modular assemblies that facilitate future component recovery. The use of standardised structural systems and recyclable stainless-steel framing creates opportunities for materials to remain within industrial supply chains over multiple building lifecycles.

The Japanese RMMT concept demonstrates an even more advanced circular model by proposing product-service arrangements where building modules and structural components can be recovered, refurbished and redeployed by manufacturers at the end of their service life. Such approaches shift the industry away from traditional linear ownership models towards circular asset management systems.

Across the case studies, several common characteristics of successful closed-loop systems were identified:

- Design for disassembly and non-destructive material recovery.
- Manufacturer take-back schemes.
- Refurbishment and remanufacturing programs.
- Standardised components that facilitate reuse across projects.
- Digital records supporting future material identification.
- Long-term supplier partnerships and circular procurement arrangements.

These approaches not only reduce waste generation but also create new economic opportunities by retaining material value within supply chains.

3.3 Industry Drivers, Key Barriers and Enablers

The research identified several major barriers and enablers affecting the implementation of circular economy principles in factory-built housing, including the incorporation of recycled content materials and products in modular housing projects. These factors must be understood and addressed to successfully apply global best practices in New South Wales. **Table 3.1** below summarises the barriers and enablers to the integration of recycled materials and circular economy principles and practices in factory-built modular housing identified during this initial literature review.

Table 3.1 *Barriers and enablers to the integration of recycled materials and circular economy principles and practices in factory-built modular housing (Source: Bradfield Development Authority, 2025).*

Barriers	Barrier Description	Enablers and recommendations
Cost	Procurement of recycled content materials may incur a cost premium. This can be both real and perceived.	Recycled content requirements should be communicated at the tender stage. This allows contractors to plan and price accordingly. Early engagement with suppliers enables the costs to be understood and considered. Incentivised targets and requirements can be used to encourage use of recycled content.
Hazardous materials	There is a risk that use of existing or waste materials may result in the incorporation of hazardous content into new products.	Products and materials can be tested for hazardous substances. The Living Building Challenge Red List provides a list of chemicals representing the “worst in class” substances prevalent in the building industry that pose serious risks to human health and the environment.
Impact on performance	There is uncertainty around material performance when additional recycled content is incorporated. Concerns may include structural, durability and constructability impacts.	Trials of new and emerging material technologies can allow performance to be tested in small scale, low risk applications. Sharing case studies can provide insight into material performance in previous trials or full-scale use. Documenting lessons learnt can inform future uses.

Barriers	Barrier Description	Enablers and recommendations
Standards and compliance	There can be uncertainty around compliance with standards when incorporating new recycled content or innovative materials.	Where a product does not meet applicable standards and specifications, it is recommended to engage with suppliers to obtain further information. Additional supplier testing or an exception from meeting project requirements may help to overcome these challenges. Testing of new materials in small scale pilots may also provide the confidence for their wider adoption.
	Existing standards and specifications may be out of date and/or limit the use of recycled content or new innovative materials.	Consider reviewing existing standards and specifications to allow the use of new materials. Also consider harmonising intra and inter-state building material specifications to provide more certainty to suppliers seeking to scale up their production of recycled content and new innovative materials.
Regulatory and certification gaps	While Building Codes and supporting standards ensure safety, their specificity can inadvertently inhibit innovation. The lack of established guidance and standards to support circular practices (e.g., standardised design for disassembly guidelines or the use of high recycled content structural elements) creates extra hurdles for project teams.	Review, harmonise and update intra and inter-state Building Codes and supporting standards to facilitate the implementation of circular design and construction practices at scale. Set clear targets and mandates for minimum recycled content levels across major material types and/or overall social housing units in public projects; and requirements for circular design and circular construction techniques in tender documentation to send signals that stimulate innovation and investment.
	Built environment rating schemes don't always recognise and reward circular design and construction practices, creating a lack of incentives to move beyond business as usual.	Actively lobby the built environment rating schemes (e.g., GBCA Green Star, IS Rating, WELL) to recognise and reward circular design, the use of high recycled content and circular materials and products. Support the rapid adoption of proposed changes to the Green Building Council of Australia's Responsible Products Framework (Version B), which include a significant focus on the circular flow and use/reuse of construction materials and requirements for EPDs and product carbon footprints, which will help to drive change.

Barriers	Barrier Description	Enablers and recommendations
Supplier relationships	Existing relationships exist with suppliers who may not offer recycled content materials	Contractors procuring materials could be provided with a list of suppliers with the desired recycled content material types and quantities. Education and knowledge sharing across the supply chain can help to demonstrate possibilities and considerations for alternative products.
Supply chain limitations	For some recycled content materials, there may be fluctuations in availability and inconsistent product quality. Limited availability of waste material feedstock for manufacturers is a key cause.	Specifications should be written to ensure recycled content materials are pursued, even if some of the material must be virgin sourced due to a lack of availability. Waste materials on site, such as pipe offcuts, can be segregated and returned to manufacturers to increase feedstock.
	Imported recycled content materials can increase uncertainty and reduce traceability of the provenance, quality and quantity of recycled content in a product or material.	Request evidence of consistent use of recycled content from suppliers. Evidence provided by suppliers can include: EPDs, third-party verified recycled content claims, material and product specifications, laboratory test results, contracts and sales agreements and production documentation for recycled materials purchased and incorporated into finished products and materials.
Tender requirements	Without explicit recycled content requirements included in tender documentation, it is likely that a business-as-usual approach will be taken to streamline procurement.	Recycled content requirements should be included in tender documentation. High level targets can provide flexibility to designers to adopt innovative materials. Package or material specific requirements can diversify the use of recycled content across a wider variety of materials.
	Many project developers and specifiers are risk averse and seek to rely on historical proven practices. This can limit the use of 'second life ready' building materials and components, or the implementation of some circular economy strategies – e.g., the use of design for disassembly connectors, reusable modular components.	Include specific tender requirements to encourage the use of durable, modular and circular building materials and products that have the potential to be reclaimed, repurposed or reused across multiple building lifecycles. Actively integrate circular economy strategies into tender documentation – e.g., design for disassembly, repair, refurbishment and reuse. Include the use of natural, rapidly renewable or regenerative materials in tender documentation – e.g., bamboo, timber, natural rubber, hemp, straw, etc.

Barriers	Barrier Description	Enablers and recommendations
Verification and quantification	Verifying the source and quantity of recycled content in a material can form a barrier to procurement.	It is recommended to select suppliers who use recycled content verification schemes. Direct engagement with suppliers is important to understand their products and availability. Include requirements for verified recycled content traceability in line with the Australian Government's National Framework for Recycled Content Traceability.
	A lack of digital transformation in the built environment can create situations where material and product information is hard to find and share, hindering project procurement, development and the use of recycled materials and innovative new materials.	Emerging traceability and digital platforms are enabling greater confidence in using recycled materials. For example, real-time tracking systems and QR-coded materials are being trialled to provide digital audit trails of recycled content from supplier to site (DCCEEW, 2025). BIM models enriched with material metadata ("digital twins") and product lifecycle information can support the identification of 'second life ready' materials and the creation of end-of-life or circularity plans, helping to track material quantities and locations for future recovery. As these tools mature, they will reduce the administrative burden and risk of including recycled content and other circular economy strategies, like design for disassembly, thereby encouraging wider uptake.

3.4 Global vs Australia Context – GAP Analysis

The international review demonstrated that leading jurisdictions are increasingly embedding circular economy principles into building regulation, public procurement and industrial policy, moving beyond voluntary sustainability initiatives towards mandatory requirements for embodied carbon, recycled content verification and whole-of-life assessment. These approaches provide an important benchmark for evaluating Australia's current policy landscape and identifying opportunities to strengthen circular economy outcomes within modular housing.

Recent Australian research indicates that while the policy direction towards a circular built environment is well established, implementation remains fragmented. The study by Shooshtarian, et al. (2025) summarised in **Figure 3.9**, found that although stakeholders generally support the transition to a circular economy, current Australian policy frameworks are not considered sufficient to drive the widespread use of products with recycled content (PwRC) in the built environment.

Among the seventeen policy instruments assessed, Extended Producer Responsibility, sustainable procurement policies and carbon pricing mechanisms were identified as having the greatest potential to increase demand for recycled-content products. Conversely, national policy settings were generally perceived as less effective than several state-based initiatives, highlighting the need for greater consistency, stronger implementation mechanisms and improved alignment across the Australian policy landscape.

Australia has also continued to strengthen its policy framework through initiatives such as the NABERS Embodied Carbon Rating (NABERS, 2026), evolving government procurement requirements, and the progressive integration of embodied carbon reporting into planning and regulatory processes. New South Wales has emerged as a national leader, incorporating embodied carbon reporting within planning pathways for new developments and promoting the use of independently verified product data to support carbon assessment. Collectively, these developments indicate that Australia is transitioning from voluntary guidance towards more structured disclosure and verification requirements, although nationally consistent embodied carbon performance standards and whole-of-life carbon regulations have not yet been established.

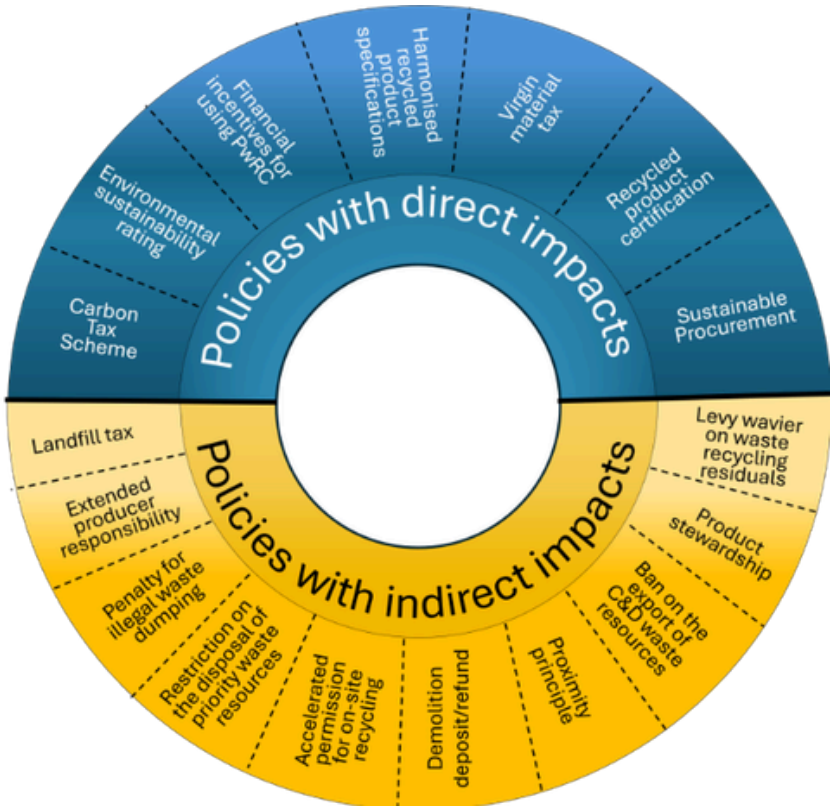


Figure 3.9 *Circular Economy (CE) policy instruments with direct and indirect impacts on the use of products with recycled content (PwRC)*

Figure 3.10 and **Table 3.2** compare Australia's current policy and regulatory landscape with leading international jurisdictions reviewed as part of this study. The comparison indicates that Australia performs comparatively well in developing voluntary guidance, circular economy strategies and recycled content frameworks. Recent policy developments, particularly in New South Wales, demonstrate increasing momentum towards embodied carbon disclosure through planning policy, procurement requirements and voluntary national assessment tools such as NABERS Embodied Carbon. However, most leading international jurisdictions have progressed further in translating these principles into mandatory requirements.

Countries such as Sweden, France and the United Kingdom have introduced embodied carbon reporting or whole-of-life carbon requirements for new buildings, while Singapore has embedded prefabricated construction and carbon assessment within broader regulatory frameworks. Germany has advanced digital material passports and building information modelling to support future material recovery, and Canada and the United States have increasingly used government procurement to stimulate market demand for low-carbon and recycled-content products. Compared with these jurisdictions, Australia's current approach remains centred on disclosure, transparency and procurement recommendations, rather than nationally consistent embodied carbon limits, legislated targets or mandatory whole-building lifecycle assessment requirements.

For Homes NSW, these findings reinforce that increasing recycled content should be considered as part of a broader transition towards circular procurement. While recycled content remains an important performance indicator, international experience demonstrates that the greatest outcomes are achieved when procurement incorporates embodied carbon, lifecycle thinking, product traceability and design for future material recovery.

Appendix A includes further information on the mapping of Australian and international policy and regulation.

Figure 3.10 *Gap Analysis: Australia regulation and guidance versus world-leading countries*

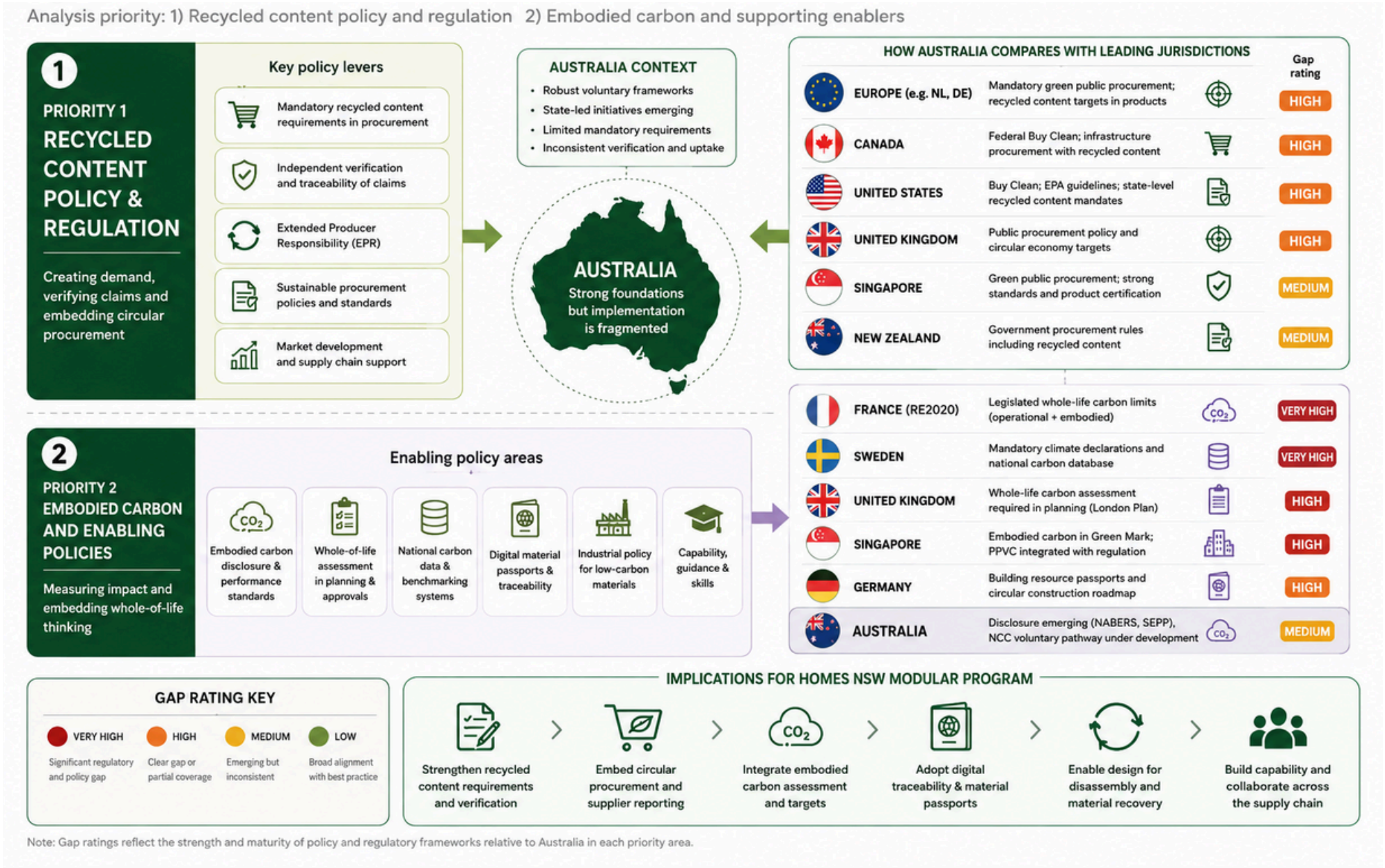


Table 3.2 *Gap Analysis: Australia vs. world-leading countries*

Country	Where comparator is ahead of Australia	Australia gap highlighted	Gap rating	Implications for Australia / NSW
Canada	Federal procurement requires whole-building life-cycle assessments and embodied-carbon requirements for multiple materials (incl. steel and reinforcement).	Australia relies on voluntary circular economy and traceability frameworks; no mandatory national embodied-carbon procurement standard for buildings.	High	Australia lacks strong federal procurement leverage. Opportunity to mandate low-carbon materials in public housing and infrastructure.
United States	Strong Buy Clean architecture via GSA/EPA with EPD-based thresholds and sustainable procurement rules.	Australia has stronger circular economy framing but weaker procurement-driven demand for low-carbon materials.	Medium –High	Gap is not policy intent but market activation via procurement at scale.
United Kingdom	Cities (e.g. London) require Whole Life Carbon assessments in planning approvals.	Australia does not systematically require WLC assessments in planning or building approval pathways.	High	Major gap in embedding embodied carbon into planning systems and development approvals.
New Zealand	"Building for Climate Change" programme includes structured embodied-carbon measurement and regulatory pathway design.	Australia lacks a defined national building-sector embodied carbon regulatory trajectory.	Medium	Australia is comparable in ambition but behind in regulatory clarity and implementation pathway.
France	RE2020 regulates operational + embodied carbon across building lifecycle.	Australia has no binding national building carbon regulation for new buildings.	Very High	Clear gap in mandatory embodied-carbon performance standards for buildings.
Germany	Advanced circular construction tools, BIM integration, and development of building resource passports.	Australia has traceability guidance but no integrated material passport or BIM-linked lifecycle system.	High	Opportunity to develop digital building material passports for circularity and recovery.

Country	Where comparator is ahead of Australia	Australia gap highlighted	Gap rating	Implications for Australia / NSW
Sweden	Mandatory climate declarations for new buildings and national climate database; movement toward limit values.	Australia lacks mandatory climate declarations and national benchmarking database.	Very High	Key missing infrastructure for future carbon caps and benchmarking policies.
Singapore	PPVC embedded in regulation; Green Mark 2021 includes embodied carbon and whole-life carbon tools.	Australia has modular guidance but limited regulatory integration and weaker carbon performance requirements.	Very High	Singapore represents a fully integrated modular + carbon regulation model.
China	Large-scale prefabrication policy, demonstration cities, and strong state-led industrialisation.	Australia lacks coordinated national industrialisation program for modular construction.	High	Gap is scale and system coordination rather than policy absence.
Japan	Long-life housing standards and strong construction recycling and durability frameworks.	Australia focuses more on circular materials than long-term building stewardship.	Medium	Opportunity to strengthen design-for-durability and adaptive reuse frameworks.

3.4.1 Australian Case Studies

Although Australia has not yet implemented the same level of regulatory integration observed internationally, several domestic projects demonstrate that many circular economy principles are already technically feasible within local construction conditions.

Design for Disassembly and Reuse

The Legacy Living Lab (L3) in Western Australia was designed as a modular building that can be disassembled, incorporating bolted steel connections, reusable structural elements and non-destructive waterproofing systems. Project analysis found that approximately 16 tonnes of structural steel were retained for future reuse, and that design for disassembly contributed to an estimated 60% reduction in life-cycle greenhouse gas impacts compared with conventional demolition and recycling pathways (Curtin University/The Legacy Living Lab, 2026). **Figure 3.11** illustrates the completed L3 building.



Figure 3.11 *The Legacy Living Lab (L3) finished build*
(Source: Curtin University/The Legacy Living Lab, 2026)

Designing buildings for adaptability and multiple future uses

As mentioned in **Section 3.2,** adaptability is a key circular design principle that extends building service life by enabling structures to accommodate changing user requirements, demographic shifts and evolving functional needs. Unlike traditional buildings designed for a single purpose, adaptable modular buildings can be reconfigured, expanded, relocated or repurposed with minimal material loss.

The Legacy Living Lab in Western Australia was designed with open-plan floorplates and modular spatial arrangements that enable future changes in occupancy and function without major structural intervention. **Figure 3.12** illustrates how The Legacy Living Lab utilises modular building techniques to provide a flexible, reconfigurable floorplan, while at the same time being able to be disassembled and relocated.



Figure 3.12 *The Legacy Living Lab showing open, reconfigurable floorplan and an architectural template that hides its modular nature (Source: Curtin University/The Legacy Living Lab, 2026 (a))*

Whole-of-life and beyond first life thinking

Whole of life thinking made it easier for the Legacy Living Lab to make informed decisions about how to use lower embodied carbon and higher recycled content materials (e.g., reuse of structural steel, use of recycled drinks bottles in thermal insulating ceiling panels and stair treads made from 100-year-old jarrah salvaged from a disused factory), ultimately demonstrating both closed loop thinking and significant greenhouse gas reductions through the use of these materials (Curtin University/The Legacy Living Lab, 2026 (a)). A whole-of-life approach also allowed for the evaluation of how to address end-of-life outcomes and future material recovery and reuse.

Together, these examples demonstrate that many of the circular economy principles identified through the international review — including design for disassembly, material reuse, whole-of-life thinking and integration of recycled-content products — are already achievable within Australian construction. However, broader adoption will depend on stronger procurement frameworks, greater supply chain transparency and consistent methods for verifying recycled content across major material streams. These findings provided the foundation for the material and supply chain assessment presented in the following chapters of this report, where the opportunities for applying these principles to the MOOV modular dwelling were examined in detail.

3.5 Applicability to Homes NSW and Opportunities in Australian Context

The global best practices identified in this review highlight clear opportunities for Homes NSW to advance circular economy objectives through its modular housing program. By learning from international experience and leveraging local strengths, Homes NSW can position itself as a leader in sustainable modular construction. Key recommendations include:

Design for Disassembly and Reuse

Both international and domestic case study examples demonstrate that design for disassembly (DfD) is most successful when incorporated during early design stages and supported by modular manufacturing processes. The evidence suggests that future Homes NSW modular housing programs could significantly increase asset longevity and material recovery (thereby securing future supplies of recycled materials) by adopting standardised mechanical connections, accessible service routes and reusable structural systems.

Modular standardisation and interchangeability

Standardisation was identified as a critical enabler of circularity, scalability and cost efficiency across the modular housing sector. Homes NSW should work with its suppliers to agree standardised module dimensions, component interfaces and manufacturing processes to facilitate easier replacement, refurbishment, relocation and reuse of building elements throughout their lifecycle. This would also create opportunities for 'second life ready' materials and building components or modules.

Designing buildings for adaptability and multiple future uses

As mentioned in Sections 3.2 and 3.4 above, adaptability is a key circular design principle that extends building service life by enabling structures to accommodate changing user requirements, demographic shifts and evolving functional needs. Unlike traditional buildings designed for a single purpose, adaptable modular buildings can be reconfigured, expanded, relocated or repurposed with minimal material loss. Homes NSW should work with its suppliers to explore the potential for modular social housing where circular design and construction allow for buildings to be reconfigured based on the changing life stages, composition and daily needs of their occupants.

Integration of digital platforms for material traceability

As digital technologies are increasingly recognised as critical enablers of circular construction, with material traceability systems providing information about the composition, location, performance and future reuse potential of building materials and components throughout their lifecycle(s), they should form the backbone of future Homes NSW projects. Digital material passports and BIM-enabled asset management systems present a significant opportunity to improve transparency, support future component reuse and establish a foundation for circular procurement practices within government-funded modular housing programs.

Designing in durability and improving operational performance, resource and energy efficiency

The combined evidence suggests that modular housing can simultaneously deliver circularity, durability and operational efficiency benefits when supported by integrated design, manufacturing and asset management strategies. These outcomes are particularly relevant for Homes NSW, where long-term asset performance, operating costs and environmental outcomes are critical considerations alongside housing delivery objectives. Homes NSW should consider reviewing its tender requirements, specifications and environmental KPIs for modular housing to incorporate resource efficiency, operational energy efficiency and mains water saving requirements, alongside minimum durability (building life) requirements.

In conclusion, Homes NSW has a timely opportunity to integrate circular economy innovations into its modular housing program. By doing so, it can deliver not only rapid, high-quality housing development, but also demonstrate leadership in sustainable construction – aligning with government objectives and helping to catalyse a transition to a more circular construction sector in Australia. The key implications arising from the literature review and their relevance to the Homes NSW modular housing program are summarised in **Table 3.3**. Implementing the recommendations in future Homes NSW projects will allow the program to pilot these ideas, gather real-world data and adjust strategies as needed. With concerted effort and collaboration, Homes NSW can become a showcase of how circular modular housing delivers social, economic and environmental value for New South Wales.

Table 3.3 *Implications for Homes NSW Modular Program and Priority Focus Areas*

Focus Area	Key Opportunity	Global/Industry Examples	Implications for Homes NSW (Actions)
Design for Disassembly (DfD)	Standardise reversible, non-destructive modular systems	Bolted steel frames (ATCO, HOLON); screw-fixed timber (Japan RMMT); refurb reuse (Wernick, Premier Modular); full relocation (Bradfields Academy); micro-footings (The Legacy Living Lab AU)	• Embed DfD in all specifications • Require “second-life ready” modules
High-Recycled Content Materials	Increase recycled content in structural materials	Recycled steel (ATCO, HOLON); reused steel (Legacy Lab – 16t); recycled concrete trials; recycled insulation/finishes (UK)	• Set minimum recycled steel thresholds • Pilot low-carbon concrete • Mandate product-level reporting
Industrialised Prefabrication Systems	Use factory production to reduce waste, cost, and carbon	BoKlok (~90% waste reduction); TopHat (near-zero landfill); Sekisui (mass prefab); Factory OS (USA)	• Expand volumetric partnerships • Require ≥80–90% waste diversion reporting • Scale local prefab capacity

Focus Area	Key Opportunity	Global/Industry Examples	Implications for Homes NSW (Actions)
Material Passports & Digital Traceability	Digitally track materials for reuse and compliance	EU DGNB passports; Singapore BCA system; QR-coded tracking pilots	• Introduce QR-coded modules • Require EPDs + recycled content proof • Develop state-wide passport system
Circular Procurement & Policy	Use procurement to drive circular market demand	UK circular statements; France RE2020; US Buy Clean; Canada green procurement	• Set recycled content thresholds • Require circular economy plans in tenders • Align procurement with carbon caps
Modular Reuse & Second-Life Systems	Treat modular buildings as reusable assets	Wernick (~46% EC reduction); Premier multi-site reuse; Bradfields Academy lifecycle reuse; >30–50% reuse in refurb systems	• Establish modular asset bank • Require lifecycle reuse strategies • Incentivise refurbishment
Bio-Based & Low-Carbon Materials	Substitute high-carbon materials with timber/hybrids	Sweden CLT; Japan RMMT; Canada timber hybrids; Germany LCA optimisation	• Expand engineered timber adoption • Prioritise CLT/hybrid systems • Require LCA comparison
Speed + Circularity Integration	Deliver fast housing with circular outcomes	China modular (20–40% EC reduction); ATCO (40% faster, 90% waste reduction); UK MMC	• Position circularity as enabling speed • Deploy modular for social/emergency housing • Standardise reusable units
Performance Benchmarking & Carbon	Standardise lifecycle carbon and circular metrics	Sweden mandatory EC reporting; France carbon caps; Canada Step Code; UK WLC requirements	• Introduce $kgCO_2e/m^2$ benchmarks • Require lifecycle carbon reporting • Compare modular vs traditional
Supply Chain Collaboration	Co-develop circular materials with suppliers	ATCO supplier engagement; BoKlok (IKEA partnerships); Japan integrated systems; EU clusters	• Establish innovation partnerships • Pilot co-developed materials • Provide long-term procurement certainty

4 Material and Supply Chain Opportunity Analysis

This section presents the findings from **Activities 2 and 3** of the GECA Recycled Content Verification Study and focuses on the material composition, supply chain characteristics and recycled content opportunities associated with the nominated MOOV modular dwelling. The project comprises a completed single-storey volumetric modular housing unit constructed using a lightweight steel-framed system and delivered as part of the Homes NSW Modern Methods of Construction Program.

As a production-ready dwelling representative of future modular housing deployments, the project provides a valuable case study for understanding the practical opportunities and challenges associated with increasing recycled content within factory-based residential construction. **Activities 2 and 3** build directly upon the findings of the **Activity 1** Desktop Review, which examined global and Australian trends in circular economy practices, modular construction, material innovation and recycled content integration. This phase of the study applies those findings to the actual material supply chain of the MOOV dwelling through a review of project-specific bill of quantities information, architectural and construction documentation, supplier information, environmental product declarations, recycled content declarations and other supporting evidence gathered during the data collection process.

The analysis focuses on identifying material hotspots, evaluating supplier capability and data availability, assessing opportunities for recycled content uptake, and prioritising material streams that may offer the greatest potential for future circular economy outcomes. In addition to documenting the recycled content claims already being provided by suppliers to the project, the assessment considers broader opportunities associated with procurement, specification, supply chain engagement and standardisation across future Homes NSW modular housing projects. This approach recognises that the greatest opportunities for scaling recycled content are often achieved through evidence-based repeatable procurement decisions and supply chain transformation rather than through individual product substitutions alone.

4.1 MOOV Supply Chain Overview

MOOV Modular is a Sydney-based modular housing manufacturer delivering permanent residential dwellings under the Homes NSW Modern Methods of Construction Program. The company specialises in volumetric modular construction and operates an integrated delivery model encompassing design, approvals, manufacturing, site preparation, transportation and installation. With dedicated precision manufacturing facilities and a focus on repeatable housing solutions, MOOV is positioned to deliver modular housing at scale while maintaining consistency in material specification, build quality and procurement practices.

The dwelling assessed as part of this study is a completed single-storey modular housing unit comprising factory-fabricated volumetric modules that are transported to site and installed on prepared foundations. Architectural drawings (more details are available under **Appendix C**) reviewed as part of this engagement indicate a lightweight steel-framed structure supported on a screw-pier foundation system, with modules assembled offsite and crane-lifted into position during installation. The dwelling provides approximately 58 square metres of internal floor area and incorporates an open-plan living, dining and kitchen area, two bedrooms, a bathroom, integrated service zones and an external porch (Total area of 77 square metres).

4.1.1 Supply Chain Structure

MOOV's supply chain is structured around a core group of Australian-based distributors, manufacturers and specialist subcontractors, with the majority of materials procured through established trade supplier relationships. Manufacturing and assembly activities are primarily undertaken within MOOV's factory environment, with only a limited number of fit-off and installation activities completed on site following module placement.

Table 4.1 provides an overview of the key supplier relationships identified from the Bill of Quantities data. It represents the first comprehensive supply chain map for a MOOV modular dwelling and will be used as the foundation for the hotspot and opportunities analysis.

4.1.2 Key Observations on Supply Chain Structure

The supply chain spans approximately twenty material categories and more than thirty-five individual product lines, ranging from structural steel framing and flooring systems through to insulation, cladding, plasterboard linings, glazing, joinery, floor coverings and finishing materials. Several categories involve multi-tier supply chains where products pass through multiple organisations before reaching the project. For example, aluminium windows and doors are supplied through Bradnam's, while extrusion products are sourced from National Aluminium and glazing units are supplied by Glass Works Australia. Similar multi-tier relationships exist within the insulation, joinery and cladding supply chains.

Several observations emerge from the supply chain mapping exercise. First, the project demonstrates a high degree of domestic sourcing, with most major material categories supplied through Australian manufacturers or Australian production facilities. This is favourable from both a supply chain transparency and recycled content verification perspective. Second, the supply chain is relatively concentrated around a small number of major manufacturers, creating opportunities to engage strategically with suppliers capable of influencing large proportions of the dwelling's material footprint. BlueScope Steel, for example, supplies structural framing, flooring members and roof sheeting systems, making it the most significant manufacturer by estimated mass contribution. Knauf supplies both insulation and plasterboard systems, while Porta products are incorporated across multiple joinery applications including kitchen cabinetry, wardrobes and storage systems.

These characteristics create favourable conditions for future recycled content verification and procurement initiatives. The combination of standardised dwelling designs, repeatable manufacturing processes and concentrated supplier relationships provides a practical pathway for Homes NSW and MOOV to implement recycled content targets, improve material traceability and scale circular economy outcomes across future modular housing projects.

Table 4.1 *Overview of Material Categories and Supply Chain Structure, Weight Distributions with their Recycled Content Status for the MOOV Modular Dwelling*

Material Category	Distributor / Installer	Manufacturer	Primary Application	Total Weight (%)	Recycled Content Status	Priority
MAIN MATERIALS						
Structural Steel (Framing)	AusSteel	BlueScope	Wall and roof framing	8.90%	24% claimed (EPD)	HIGH
Structural Steel (Flooring)	Stratco	BlueScope	Floor joists	11.80%	24% claimed (EPD)	HIGH
Steel Roofing	Stratco	BlueScope	Roof sheeting and flashings	4.50%	24% claimed (EPD)	HIGH
Structural Flooring (Board)	Australian Panel Products	Porta	Structural floor sheeting	7.04%	40% Claimed (undergoing GECA verification)	HIGH
Structural Wet Area Flooring	Campbell Building Materials	James Hardie	Wet area flooring	1.26%	0-4% (EPD, Self-declared)	MEDIUM
Timber Battens and Framing	Campbell Building Materials	Hyne Timber	Cavity battens, Door Jambs, and feature elements	4.76%	N/A	N/A
Structural Board (Polywood)	Intafloors	*Manufacturer unconfirmed*	Wall and flooring linings (under Vinyl, Frame bracing)	0.71%	N/A	N/A
Interior Linings (Plasterboard)	Knauf	Knauf	Wall and ceiling linings	11.60%	2.26–5.87% Claimed (EPD)	HIGH
Water Resistant Linings (Plasterboard)	Knauf	Knauf	Wet area wall sheeting	1.64%	2.26–5.87% Claimed (EPD)	HIGH
Waterproofing Board (High-density polyurethane foam)	Mitre 10	MULTIPANEL	Waterproof boards & shower bases	*Not available*	N/A	N/A
Cladding (Fibre cement sheet)	Knauf	James Hardie	External wall cladding	6.18%	0-4% (EPD, Self-declared)	LOW

Material Category	Distributor / Installer	Manufacturer	Primary Application	Total Weight (%)	Recycled Content Status	Priority
Cladding Panel	CSR	Cemintel	External wall cladding	1.82%	0%	LOW
Cladding Panel	Campbell Building Materials	Weathertex	External wall cladding	2.83%	0%	LOW
Cladding Panel	Campbell Building Materials	James Hardie	External wall cladding, Roofing	1.52%	0-4% (EPD, Self-declared)	LOW
Insulation (Fibreglass)	Knauf	Knauf	Internal/External walls, ceiling and flooring	4.83%	66% with 40-80% recycled glass (EPD)	MEDIUM
Insulation	Premier Commercial Insulation	CSR Bradford	Wall wrap	0.10%	72-76% post-consumer With 80% recycled glass (EPD)	MEDIUM
Insulation	Stratco	Kingspan	Floor underlay (reflective foil)	0.12%	0%	LOW
Aluminium Windows and Doors	Bradnam's	National Aluminium / Glass Works Australia / Queensland Plastics / Doric (Hardware)	Windows and external doors	Aluminium – 1.14% Glazing – 1.06% Minor weight for other components	Aluminium – 0%	HIGH
Timber	Campbell Building Materials	*Manufacturer unconfirmed*	Architraves and Skirting, wardrobe jambs	0.84%	N/A	N/A
Door (Timber)	Campbell Building Materials	Hume Doors & Timber	Internal Doors	*Not available*	N/A	N/A
Steel Door Framing	Campbell Building Materials	*Manufacturer unconfirmed*	Internal and external doors, linen cupboard	3.21%	*Not available*	HIGH
Decking Board (Composite)	Stratco	Modwood	External deck boards	3.08%	>85% including 55% pre-consumer and 30% post-consumer (Self-Declared)	HIGH

Material Category	Distributor / Installer	Manufacturer	Primary Application	Total Weight (%)	Recycled Content Status	Priority
Kitchen Joinery	Galley Kitchens	Porta (particleboard / Polytec)	Benchtop, cabinetry	8.57% (estimated)	40% Claimed (undergoing GECA verification)	HIGH
Wardrobe Joinery	Factory Direct Wardrobes	Porta (particleboard)	Wardrobe and linen cabinetry	1.94%	40% Claimed (undergoing GECA verification)	HIGH
Flooring (vinyl)	Flooring Extra	*Manufacturer unconfirmed*	Internal floor covering	1.87%	Not available	MEDIUM
Paints and Coatings	Sneddon Painting	Haymes Paint	Internal and external finishes	*Not available*	0%	LOW
Waterproofing	My Waterproofing Co	Ardex	Wet area floors	0.06%	Not available	LOW
Tiling and Grout	My Tile and Co	*Manufacturer unconfirmed*	Wet area wall and floor tiles	4.18%	Not available	LOW
Glazing	Exclusive Glass	*Manufacturer unconfirmed*	Shower Screen	*Not available*	N/A	LOW
External Fixtures and Screening	Glass Outlet	*Manufacturer unconfirmed*	Aluminium Handrails and Screening under modules	*Not available*	*Not available*	MEDIUM
Roller Blind	Flooring Extra	*Manufacturer unconfirmed*	Blinds	*Not available*	*Not available*	LOW
Fit-off item	Eagles Plumbing	*Manufacturer unconfirmed*	Plumbing and Joinery items, Stainless steel Sink	*Not available*	*Not available*	LOW

Material Category	Distributor / Installer	Manufacturer	Primary Application	Total Weight (%)	Recycled Content Status	Priority
PACKAGING MATERIALS						
Pallet	James Hardie	*Manufacturer unconfirmed*	Packaging for boards/claddings	*Not available*	*Not available*	Low
Cardboard	James Hardie	*Manufacturer unconfirmed*	Packaging for boards/claddings	*Not available*	*Not available*	Low
Timber Glut	ITI AUS	*Manufacturer unconfirmed*	Packaging for decking	*Not available*	*Not available*	Low
Plastic Wrap	Allviron	*Manufacturer unconfirmed*	Packaging for decking	*Not available*	*Not available*	Low
MDF	Kastoria	*Manufacturer unconfirmed*	Packaging for decking	*Not available*	*Not available*	Low
Polyester Batts (LDPE)	CSR	*Manufacturer unconfirmed*	Packaging for boards/claddings	*Not available*	*Not available*	Low

Note on Weight Data

The confirmed weights above are drawn directly from the Bill of Quantities as submitted by MOOV. Several product categories were recorded with quantities expressed in linear metres, square metres or unit counts rather than kilograms, and weight conversions have been applied using manufacturer-specified unit weights where available. Categories marked 'Not confirmed' reflect products for which weight data was not provided; estimated weights for these categories were incorporated in Activity 4 (where applicable).

N/A: Not applicable.

4.2 Materials Hotspot Identification

The material hotspot assessment was undertaken to identify those material streams with the greatest potential to influence recycled content outcomes across the MOOV modular dwelling and future Homes NSW modular housing projects. Material categories were prioritised based on three criteria: their relative contribution to the dwelling material inventory, the potential for increased recycled content uptake based on current market availability and industry practice, and the availability of supporting evidence required for verification.

In addition to material quantity, consideration was given to supplier concentration, procurement influence, supply chain maturity and the potential for solutions to be replicated across future modular housing projects. This is particularly important within a volumetric modular construction model, where standardised designs and repeatable procurement practices can enable improvements to be scaled efficiently across multiple dwellings.

4.2.1 Weight Distribution by Material Category

The Bill of Quantities submitted by MOOV includes mass data for the majority of structural, enclosure and internal lining materials incorporated within the dwelling. Based on the available information, the total confirmed material mass is approximately 14,000 kilograms, excluding several categories for which weight data was not available, including internal doors, tiles, plumbing fixtures and selected fit-off components.

Table 4.1 also presents the estimated material distribution for the dwelling based on the Bill of Quantities and supplementary supplier information available at the time of assessment. The inventory indicates that material use is concentrated within a relatively small number of categories, with structural steel, engineered wood products, plasterboard systems, insulation materials and cladding products representing the largest proportion of the documented material mass. These categories subsequently formed the primary focus of the hotspot assessment and recycled content opportunity analysis presented in the following sections.

4.2.2 Hotspot Analysis

The material inventory demonstrates that the MOOV dwelling is characteristic of contemporary lightweight modular construction, with material use concentrated within a relatively small number of structural and enclosure systems. Consistent with findings from **Activity 1**, this concentration creates an opportunity to focus recycled content interventions on a limited number of material streams capable of delivering disproportionate project-wide outcomes.

The hotspot assessment identified five priority material streams: structural steel, engineered wood products, plasterboard, insulation and aluminium systems, represent approximately 60 to 65 % of the documented material inventory by weight and encompass the majority of the project's structural and building envelope components. These materials were therefore selected for more detailed assessment because improvements within these categories have the greatest potential to influence recycled content outcomes at both dwelling and program scale.

Structural Steel

Structural steel was identified as the highest-priority material stream within the MOOV modular dwelling. The Bill of Quantities confirms approximately **3.52 tonnes o**f structural steel (>25% weight of the final project) across wall framing and floor members, roof sheeting and several ancillary steel components. Beyond its material significance, structural steel represents one of the strongest opportunities for increasing recycled content across future modular housing projects. The category benefits from a mature domestic manufacturing sector, established scrap recovery infrastructure, comprehensive Environmental Product Declarations, and comparatively advanced recycled content reporting. BlueScope, the primary manufacturer supplying the project, reports an average recycled content of **24%** (18% post-consumer and 6% pre-consumer) for its flat steel products manufactured at Port Kembla, calculated in accordance with AS/NZS ISO 14021 definitions. This provides a credible baseline for the structural steel products currently incorporated into the MOOV dwelling.

While recycled content is an important circular economy indicator, it should not be considered in isolation. The environmental performance of steel is also influenced by the production route, availability of quality scrap feedstock, energy source and responsible sourcing practices. Australia's flat steel industry is currently dominated by the integrated blast furnace–basic oxygen furnace (BF-BOF) production route, which relies primarily on iron ore with recycled steel used as a supplementary feedstock. By comparison, electric arc furnace (EAF) technology primarily melts recycled steel scrap and generally enables substantially higher recycled content while also offering significantly lower greenhouse gas emissions when powered by low-carbon electricity. As Australia's electricity grid continues to decarbonise and greater quantities of high-quality scrap become available, increased adoption of electric arc furnace technology and other low-emissions steelmaking pathways is expected to play an important role in both reducing embodied carbon and increasing recycled steel utilisation across the domestic construction sector. It should be noted though that virtually all recoverable steel in Australia is already recycled, limiting additional progress from domestic sources.

International experience demonstrates that substantially higher recycled steel inputs are technically achievable under EAF production routes. Global industry data published by the World Steel Association indicates average recycled steel inputs of approximately 710 kilograms per tonne of steel produced via EAF technology (World Steel Association, 2023), while leading international manufacturers such as Nucor report average recycled content of approximately 79 % across their steel products and more than 90 % for reinforcing steel products (Nucor Corporation, 2025a, 2025b). More details are provided in **Figure 4.1**.

Although these values are not directly comparable with Australian flat steel production, they illustrate the longer-term potential for increased recycled steel utilisation as domestic manufacturing technologies, electricity decarbonisation and scrap availability continue to evolve.

Recycled Content – Averages for Nucor Products

2025 Recycled Steel Content of Nucor Products (% by Total Weight)	
Product Group	Average Recycled Content
Nucor Bar Products	98.5%
Nucor Engineered Bar Products	95.9%
Nucor Beam Products	81.8%
Nucor Plate Products	83.3%
Nucor Sheet Products	62.4%
Total Nucor Steel Combined	79.1%

Nucor Downstream Products Group

2025 Recycled Steel Content of Nucor Steel Products			
	Total Scrap Steel Used	Total Post-Consumer Recycled Content	Total Pre-Consumer Recycled Content
Vulcraft Structural Products	98.5%	93.0%	5.5%
Vulcraft / Verco Decking	62.4%	26.9%	35.5%
Nucor Grating	98.5%	93.0%	5.5%
Nucor Building Group	79.1%	51.5%	27.6%
Rebar Fabrication	98.5%	93.0%	5.5%
Nucor Tubular Products - Sheet	62.4%	26.9%	35.5%
Nucor Tubular Products - Plate	83.3%	53.5%	29.8%
Nucor Fastener Products	98.5%	93.0%	5.5%
Nucor Wire Products	98.5%	93.0%	5.5%
Nucor Insulated Panel Group Products	63.3%	24.6%	38.7%
Nucor Cold Finish - Bar	98.5%	93.0%	5.5%
Nucor Cold Finish - SBQ	95.9%	52.3%	43.6%
Skyline Steel Group	74.3%	33.0%	41.3%
Nucor Warehouse Systems	72.7%	42.9%	29.8%

Figure 4.1 *Average recycled contents for Nucor Steel products and Downstream Products Groups (Source: Nucor Corporation, 2025b)*

Engineered Wood Products

Engineered wood products are also identified as a material hotspot because they are distributed across multiple building applications and therefore offer multi-point procurement leverage through a relatively limited set of suppliers. In the MOOV dwelling, known wood-based boards and ancillary timber products already exceed **2.5 tonnes** from flooring panels, plywood and wardrobe joinery. The strategic importance of this stream is therefore not only its size but its coverage across structural flooring, internal joinery, wall build-ups and external cladding. The Bradfield guidance identifies particleboard as having the strongest recycled-content opportunity within timber systems, **with up to 80 % claimed recycled content available in the market.** Australian examples include D&R Henderson particleboard at 75 % pre-consumer plus 10–20 % post-consumer content, PFLEIDERER at 85 % total, and Porta particleboard using post-consumer content via reDirect and timber residue. Project documentation for MOOV indicates around 40 % recycled content is being claimed for selected board products from Porta, but verification of that claim remains in progress. Global practice indicates similar or higher levels are technically achievable in particleboard manufacture, although outcomes remain product- and resin-dependent. Verification readiness is medium: the category has credible market benchmarks and certification pathways, but project-specific board claims are not yet consistently verified to the standard required for program-level target setting. The near-term action is to consolidate structural flooring, joinery board and wardrobe board into one engineered-wood procurement category and require a common evidence pack covering recycled timber fibre, chain of custody, low-formaldehyde performance and declaration method. The medium-term action is to set differentiated targets for structural board, decorative board and timber cladding rather than a single wood target.

Plasterboard

Plasterboard is a confirmed material hotspot because it is a major mass contributor, supplied through a concentrated manufacturer base, and already sits within relatively mature verification frameworks even though recycled-content uplift is currently modest. The project dataset indicates approximately **1.85 tonnes** of plasterboard across standard and wet-area linings **(13.2% total weight)**. The Bradfield guidance states that Australian plasterboard is typically procured at **2–6 % claimed recycled content, with an opportunity of up to 20 % recycled content**, and also notes that recycled paper facing is already standard practice while recycled-gypsum pathways remain constrained by contamination and asbestos risks in Australia. This aligns closely with the MOOV evidence, where current product declarations indicate recycled-content values in the low single digits for the Knauf products under review. Global literature suggests the category's near-term recycled-content ceiling is often governed less by product chemistry than by access to clean, segregated gypsum recovery streams. Internationally, alternative gypsum board products and some North American products also use 100 % recycled face and back papers (USG Corporation, 2024), reinforcing the point that paper content is mature while gypsum-loop recovery remains the harder challenge.

Verification readiness is high for baseline reporting but only medium for uplift: current products are documented, but the supply-chain conditions required to move materially beyond present Australian norms are not yet mature. The near-term action is to require product-specific verified carbon and recycled-content declarations for all lining boards and to separate paper-content claims from gypsum-content claims. The medium-term action is to explore offcut segregation and take-back from modular factory environments, where clean plasterboard waste recovery is considerably more feasible than on conventional building sites.

Insulation Products

Insulation is the clearest near-term opportunity because the category already demonstrates comparatively high recycled-content levels in Australian supply and has limited technical barriers in the relevant use cases. The project Bill of Quantities records **approximately 676 kg** of glasswool batts, with a further smaller amount of wraps and reflective products (Total weight of approximately **5% of the build**). The strategic case is not driven by mass alone; it is driven by the combination of repeat use throughout the dwelling envelope, relatively standardised product specifications, good performance compatibility and strong Australian benchmark data. The Bradfield guidance identifies glasswool products claimed with up to 80 % recycled glass, and CSR Bradford currently markets several Australian-made wall and ceiling insulation products as containing up to 80 % recycled glass. The project evidence reviewed for MOOV includes Knauf ceiling and high-density batt products with reported recycled-glass content around 66 %, alongside Bradford-related documents indicating high recycled-glass content in comparable product families. This is a materially stronger benchmark than most other mainstream construction products in the dwelling. Global best practice is broadly consistent, with mineral-wool and glasswool products in international markets commonly offering high recycled feedstock where clean cullet supply is available. Verification readiness is medium-high: the category is well suited to product-family verification. The near-term action is to separate glasswool from other insulation types in specification and reporting, and to mandate product-family declarations for recycled-glass content. The medium-term action is to establish a minimum verified recycled-glass benchmark for future modular dwellings, while treating foil, foam and specialty acoustic products as separate categories.

Aluminium

Aluminium window and door systems are a smaller mass contributor but a clear strategic hotspot because they are repeatable, high-value, relatively (embodied) carbon intensive and strongly linked to procurement leverage. The project Bill of Quantities indicates a combined glazing and frame package of about 309 kg, including **approximately 149 kg** of aluminium framing. The present supply chain appears to remain largely reliant on primary or near-primary input, with project evidence indicating that product-specific recycled-content verification is not yet robust at the fabricated window-system level. That said, the Australian market is moving. The Bradfield guidance notes that domestically extruded aluminium products are typically procured at 0 % recycled content but **that up to 30 % recycled content is an emerging opportunity in Australian extrusion supply.**

Capral has already trialled and then integrated primary billet options containing 15 % and 30 % recycled content, while Rio Tinto, Capral and Sims have announced an Australian closed-loop pathway returning post-production scrap to billet with a minimum 20 % recycled content (Capral Aluminium, 2024). Tomago has separately publicised a remelt arrangement for approximately 550 tonnes of production scrap annually (Tomago Aluminium, 2024). Globally, Hydro CIRCAL now provides a stronger benchmark with verified products containing at least 75 % post-consumer scrap, and in some cases 100 % post-consumer scrap (Hydro, 2024). Verification readiness for the MOOV project is currently medium: the pathway is visible, but chain-of-custody from billet to extrusion to fabricated frame is not yet sufficiently project-specific.

Other Material Categories

Several additional categories, including fibre cement cladding, composite decking and vinyl flooring, also demonstrated opportunities for recycled content uptake. However, their overall influence on project-level outcomes is lower due to either smaller material volumes, limited data availability or lower levels of supplier transparency. These categories remain relevant for future investigation but are considered secondary priorities relative to the five primary hotspot material streams.
The assessment further identified a strong correlation between supplier concentration and opportunity scale. A relatively small number of manufacturers, including BlueScope, Knauf, Porta and National Aluminium, influence a significant proportion of the dwelling's material footprint. This concentration suggests that targeted engagement with a limited number of strategic suppliers may achieve greater recycled content outcomes than attempting to engage every supplier across the project supply chain. Such an approach aligns with broader industry trends in modular construction, where standardisation and repeatability enable procurement interventions to be implemented consistently across large numbers of dwellings.

Figure 4.2 below provides the summary findings of the material hotspot analysis and the opportunities to achieve an uplift in recycled content in the MOOV Modular dwelling included in this pilot study.

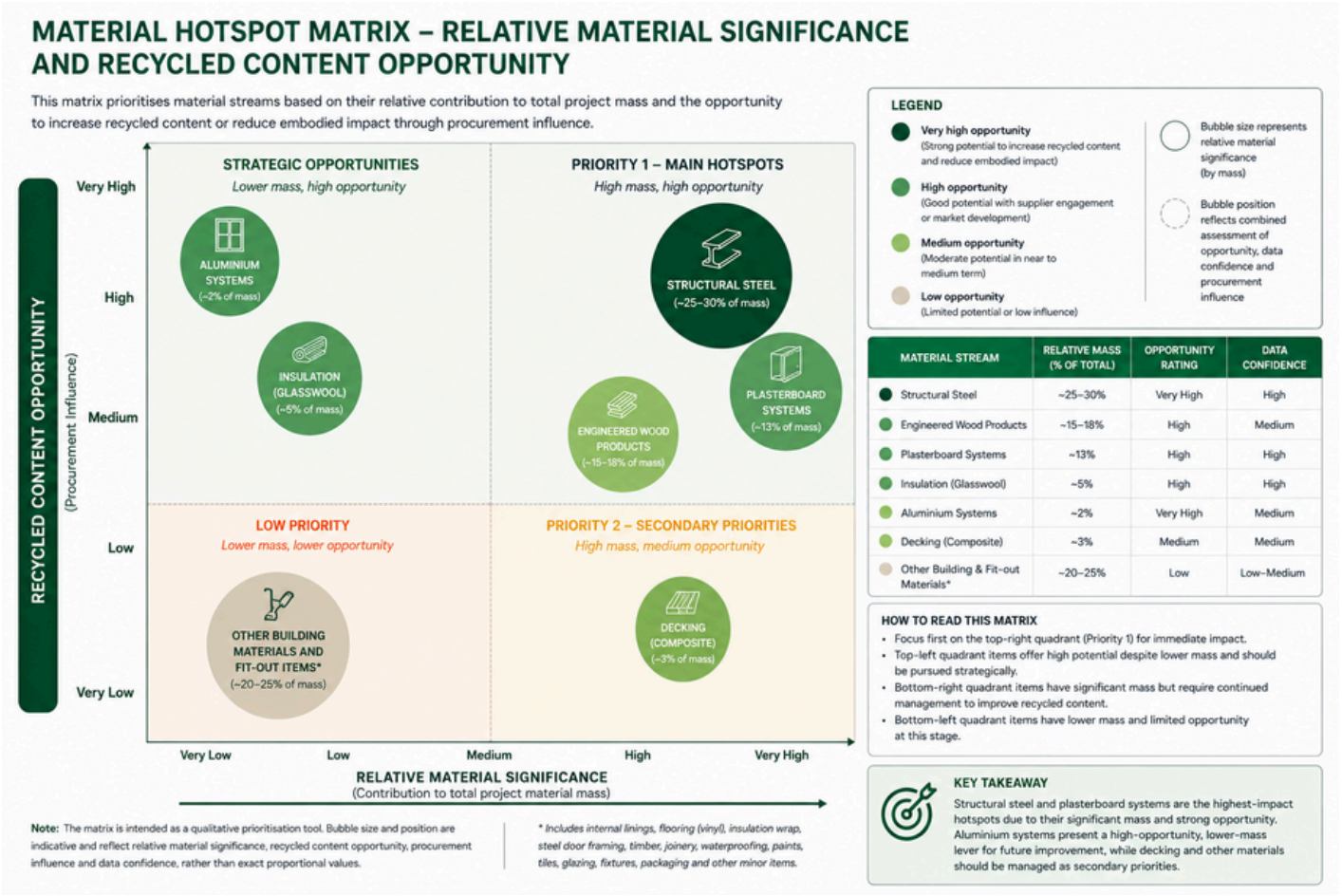


Figure 4.2 *Material Hotspot Matrix: Material Significance and Recycled Content Opportunity*

4.3 Supplier Capability and Data Availability Assessment

The supplier capability assessment indicates that MOOV's current supply chain has a relatively strong foundation for recycled content verification, particularly for major material streams where established manufacturers already publish Environmental Product Declarations, recycled content statements or certification documentation. The highest data maturity was observed for steel, insulation, plasterboard and selected engineered wood products. These categories are supplied by large manufacturers with existing environmental disclosure systems and, in several cases, recycled content claims that are already supported by product-specific or manufacturer-level documentation.

The assessment also identified a clear distinction between general sustainability disclosure and recycled content verification. Several suppliers provide Environmental Product Declarations or technical data sheets, but these documents do not always provide sufficient detail to verify recycled content claims in accordance with ISO 14021. This is particularly relevant where claims are presented as average recycled content, mass balance values encompassing a wide array of products, recycled feedstock ranges or product-family data rather than product-specific values for the materials supplied to the MOOV dwelling.

Steel has the strongest verification pathway among the major material streams. BlueScope provides Environmental Product Declarations and recycled content information for key products used in the project, including TRUECORE steel and GALVASPAN-type structural products.
Aluminium has a more complex data profile. The window and door systems used in the dwelling are supplied through Bradnam's, with aluminium extrusions understood to be sourced from National Aluminium and upstream billet supply linked to Rio Tinto. Supplier engagement indicates that National Aluminium primarily uses virgin aluminium log, with fabrication scrap recovered externally through Sims Metal. The Rio Tinto New Zealand Aluminium Smelter billet Environmental Product Declaration reviewed during the assessment indicates approximately 7 % pre-consumer recycled content in the billet, but further confirmation is required to determine whether this is representative of the billet used in the specific extrusions supplied to Bradnam's. This material stream therefore has high strategic importance but medium verification readiness at this stage.

Insulation demonstrates strong recycled content potential and comparatively good data availability. Knauf glasswool products reviewed for the project include Environmental Product Declarations reporting recycled glass inputs, with the project data recording a recycled content figure of 66 % for selected products. CSR Bradford documentation and industry information also indicate that glasswool insulation products can contain high levels of recycled glass; Bradford product information reports up to 65 % recycled glass for certain blanket products, while other Bradford-related material in the project dataset records recycled content in the range of 72–76 % for wall wrap and insulation-related products.

Engineered wood products show moderate to strong opportunity but uneven verification readiness. Porta and related board products appear across structural flooring, kitchen joinery, wardrobe cabinetry and other internal applications. The project data records recycled content claims of approximately 40 % for selected particleboard products, with evidence including Environmental Product Declarations, GreenRate certification and chain-of-custody documentation. However, some recycled content claims remain under verification or are based on volume-credit approaches, which require further assessment before being treated as verified project data.

Plasterboard has strong data availability but more limited recycled content uplift at present. Knauf plasterboard products used in the project are supported by Environmental Product Declarations and GECA certification for selected products. The recycled content recorded in the project data is modest, generally in the range of 2.26–5.87 %, largely associated with recycled paper facing rather than recycled gypsum inputs. This suggests that plasterboard is a significant material stream by mass and data maturity, but near-term recycled content uplift may depend on the development of more mature plasterboard take-back and recycled gypsum supply chains. Australia has made significant progress in establishing industry-led product stewardship initiatives for plasterboard. Major manufacturers, including CSR Gyprock (CSR Limited, 2023) and Knauf (Knauf Gypsum Pty Ltd, 2023; Waste Initiatives, 2023), operate national plasterboard take-back and recycling programs for clean construction offcuts and selected demolition waste, while specialist recyclers such as REGYP provide collection and processing infrastructure capable of recovering up to 95 % of gypsum waste for reuse in agricultural, engineering and new manufacturing applications.

These initiatives provide an important foundation for increasing recycled gypsum availability over time; however, widespread uptake will continue to depend on effective source separation, contamination control, collection logistics and market demand for recycled gypsum products.

For secondary material streams such as cladding, vinyl flooring, waterproofing systems, tiles, plumbing fixtures and fit-off components, data availability is more variable. Some manufacturers provide EPDs, but recycled content claims are either absent, low, self-declared or not yet supported by sufficient product-specific evidence. These materials should remain within the broader data collection framework but are not recommended as the first focus for detailed verification unless they are later shown to contribute materially to the project baseline or provide a clear procurement opportunity.

The assessment also identified that many of the priority material streams are supplied through well-established Australian manufacturing sectors, providing a strong foundation for recycled content verification and future procurement initiatives. Australia has established domestic production capability across key material categories, including structural steel, aluminium, engineered timber and a broad range of construction products. Major manufacturers such as BlueScope and Liberty Steel, Rio Tinto, Alcoa and Tomago Aluminium, together with construction product suppliers including James Hardie, CSR, Brickworks, Adbri and emerging engineered timber manufacturers, represent an established industrial base capable of supporting increased recycled content uptake.
This domestic manufacturing capability provides Homes NSW with an opportunity to leverage procurement to advance both circular economy objectives and local industry development. Realising this opportunity will depend on robust product verification, transparent supply chain traceability and consistent reporting methodologies that provide confidence in recycled content claims.

Overall, supplier capability is strongest where the project is connected to major manufacturers with established environmental disclosure systems, including Environmental Product Declarations, recycled content declarations and supporting technical documentation. This is particularly evident for manufacturers such as BlueScope, Knauf, CSR Bradford and selected engineered wood suppliers. The principal data gaps relate to product-specific recycled content verification, differentiation between pre-consumer and post-consumer recycled content, traceability of upstream feedstocks, and the completeness and consistency of weight data across all material categories. These gaps have been addressed within this report to the extent possible using currently available supplier evidence, and are reflected in the verification of recycled content baseline study under Chapter 5. Closing the remaining gaps should now be treated as an ongoing supplier engagement and reporting task for future Homes NSW modular housing projects.

4.4 Priority Material Streams and Opportunities for Recycled Content Uptake

The material hotspot assessment identified five priority material streams that warranted further investigation through the recycled content verification phase: steel, aluminium, insulation products, engineered wood products and plasterboard systems. Together, these categories account for the majority of the documented material inventory, represent the highest-value procurement packages, and are supplied through a relatively small number of manufacturers with established environmental reporting systems.

Although each material presents different technical constraints and market maturity, several common themes emerged across the assessment. First, supplier capability is generally strongest where products are supported by Environmental Product Declarations, product-specific recycled content declarations or recognised certification schemes. Second, recycled content claims are often available at manufacturer or product-family level but are not always sufficiently specific to the products supplied to the project. Finally, there remains considerable variation in the availability of evidence supporting the distinction between pre-consumer and post-consumer recycled content, highlighting the importance of consistent reporting methodologies aligned with AS/NZS ISO 14021.

The assessment also demonstrates that increasing recycled content should not be considered as an isolated procurement objective. For several high-impact materials, particularly steel and aluminium, recycled content should be evaluated alongside embodied carbon, manufacturing pathway, responsible sourcing and long-term material circularity. This broader approach better reflects emerging government procurement policies and recognises that the greatest environmental benefit may result from optimising multiple sustainability outcomes simultaneously rather than maximising recycled content alone.

The strategic opportunities identified for each priority material stream are summarised in **Table 4.2** below.

The opportunity assessment confirms that targeted engagement with a relatively small number of strategic suppliers has the potential to influence a significant proportion of the dwelling's material footprint. Manufacturers including BlueScope, Knauf, National Aluminium, Porta and associated board suppliers collectively supply many of the highest-volume material categories used throughout the modular dwelling. This concentration provides a practical pathway for improving recycled content outcomes through standardised specifications, consistent reporting requirements and coordinated supplier engagement rather than product-by-product procurement.

Table 4.2. *Priority Material Streams: Current Position, Opportunities and Recommended Actions*

Material Stream	Current Position	Strategic opportunities	Priority Actions
Steel	Strong supplier documentation and verified recycled content baseline. Largest material stream within the dwelling.	Integrate recycled content, embodied carbon and responsible sourcing into future procurement requirements.	Require product-specific Environmental Product Declarations and AS/NZS ISO 14021 recycled content declarations. Progressively introduce procurement preferences for lower-emissions steel products as they become commercially available.
Aluminium	Very low Recycled Content. Moderate verification maturity. Product-level recycled content requires further confirmation through the supply chain.	Support transition towards verified recycled-content aluminium and emerging closed-loop billet production within Australia.	Confirm chain of custody from billet through extrusion to fabricated window systems and investigate higher recycled-content extrusion products for future projects.
Insulation	High recycled glass content already demonstrated for selected products with relatively mature documentation.	Establish consistent recycled-content benchmarks across insulation products used within modular housing.	Separate glasswool from other insulation types in reporting and require product-family recycled content declarations for all insulation products.
Engineered Wood Products	Moderate recycled content currently available with verification progressing across several product groups.	Develop a coordinated procurement approach for flooring, joinery and board products supplied by common manufacturers.	Require evidence covering recycled timber fibre, chain of custody, formaldehyde performance and declaration methodology across all engineered wood products.
Plasterboard	Strong Environmental Product Declaration coverage but relatively low recycled gypsum content.	Improve closed-loop gypsum recovery and strengthen recycled gypsum supply into new plasterboard manufacture.	Continue product-level verification while exploring factory offcut segregation and manufacturer take-back schemes to improve recycled gypsum recovery.

The findings from this assessment provide the basis for the rest of the project.

5 Recycled Content Baseline, Verification and Benchmarking

This section consolidates the recycled-content evidence, verification status and alignment with relevant frameworks for the six material streams assessed within the MOOV modular dwelling. It draws on the final supplier questionnaire responses and supporting documentation for five priority material categories identified in the opportunity analysis (structural steel, plasterboard, engineered wood products, aluminium and insulation) as well as composite decking, which has been included as a secondary material stream due to its relatively high recycled-content claims.

The evidence collected through this study is sufficient to establish a provisional recycled-content baseline across the six material streams assessed within the MOOV modular dwelling. However, the evidence base varies in quality, completeness and level of independent assurance between material categories. Accordingly, the dwelling baseline should be interpreted as a combination of verified supplier data, publicly available information and claims that remain subject to further substantiation.

Based on the evidence available at the time of assessment, structural steel, plasterboard, composite decking and insulation products provide a reasonable basis for inclusion in the project baseline, although the level of confidence and traceability differs between streams. The recycled-content claim for engineered wood products remains subject to GECA's ongoing claim-verification process, while National Aluminium has confirmed that the products supplied currently contain no recycled content, establishing an important baseline against which future improvements can be measured.

Given the varying levels of evidence and assurance available, each material stream has been assigned an evidence-based reporting status rather than being uniformly classified as verified. To provide a consistent basis for assessment, the recycled-content claims were evaluated against four complementary frameworks: AS/NZS ISO 14021, the National Framework for Recycled Content Traceability, the NSW Recycled Content Reporting Guide and GECA's recycled-content verification criteria. The assessment methodology adopted in this study considers the accuracy, adequacy, transparency and reliability of the evidence provided, together with the extent to which suppliers can demonstrate traceability and independent assurance. The following sections describe the assessment approach in detail and present the alignment of each material stream against these frameworks, along with recommendations to strengthen recycled-content reporting across future Homes NSW modular housing projects.

5.1 Assessment Methodology

5.1.1 Evidence collection methodology

GECA developed a structured supplier questionnaire covering calculation methodology, reporting period, chain of custody, traceability, quality assurance, confidence levels, barriers and future opportunities. Suppliers were asked to provide supporting evidence including EPDs, internal calculations, purchasing records, supplier declarations and certification documents.

5.1.2 Four assessment criteria

Table 5.1 defines each of the implemented assessment criteria and outlines the factors that move a material stream up or down the evidence hierarchy. **Sections 5.3** and **5.4** then apply these criteria to each of the six key material streams.

Table 5.1 *Four Assessment Criteria: Accuracy, Adequacy, Transparency and Reliability, with What Raises or Lowers Each Rating*

Criterion	Assessment question	What raises the rating	What lowers the rating
Accuracy	Is the reported value based on a clear calculation method tied to the supplied product?	Product-specific method; clear calculation; defined scope and boundaries	Site-average values and estimates, unclear recycled content mapping, or mixed boundaries
Adequacy	Is the submitted evidence complete enough to review and reproduce the claim?	Complete calculation, input records, supplier evidence, pre/post consumer split and product mapping and production logs all available	Missing evidence, certificates, calculation records, or incomplete coverage
Transparency	Does the declaration clearly state what is counted, on what basis, and over what period?	Clear inclusions/exclusions, averaging basis, period and known limitations	Ambiguous wording, uncertain exclusions, undefined period, or unclear basis
Reliability	Is the claim supported by independent assurance, auditable traceability, or a recognised mechanism?	Third-party verification, recognised certification, auditable chain of records	Supplier estimate only, no external assurance, or a weak traceability chain

5.1.3 Claim status classification

The outcome of the verification assessment for each material stream is presented using one of five claim status categories. As shown in **Table 5.2**, these reporting tiers reflect the level of confidence in the recycled content claims based on the evidence gathered and assessed through the verification process as part of this chapter.

Table 5.2 *Claim Status Classification: Definitions of the Five Reporting Tiers*

Status	Meaning
Verified	Sufficient evidence exists for the claim to be treated as independently substantiated for the specific product.
Partially Substantiated	Credible, useful evidence exists, but one or more material gaps remain before verification can be finalised.
Under Verification	A claim has been proposed, but the current evidence package is not yet sufficient for acceptance.
Supplier-Confirmed Baseline	A baseline statement has been provided and is suitable for recording as a current position but is not a positive verified recycled-content claim.
Data Gap	The material remains in scope, but no evidence has been provided.

5.1.4 Framework benchmarks used

Four frameworks were used as benchmarks throughout this assessment. **Table 5.3** summarises the role that each framework plays in evaluating recycled content claims, while **Section 5.4.2** applies all four frameworks to each material stream and presents the resulting scores.

Table 5.3 *External Framework Benchmarks Used in This Assessment and the Role Each One Plays*

Framework	Role in this assessment
AS/NZS ISO 14021:2016	Primary benchmark for assessing whether a self-declared recycled-content claim has been defined, calculated and communicated in accordance with internationally recognised principles, including the treatment of pre-consumer and post-consumer material.
National Framework for Recycled Content Traceability	Australian Commonwealth Government supply-chain traceability benchmark used to assess whether the recycled-content claim can be linked to the supplied product through records, management systems, chain-of-custody arrangements or assurance mechanisms.
NSW Recycled Content Reporting Guide (DCCEEW, Feb 2026)	Government reporting benchmark used to assess alignment with current NSW reporting categories, templates and disclosure expectations for recycled-content claims.
GECA Criteria for Recycled Content Verification Claims	Product-level assurance benchmark used to assess whether the available evidence is sufficient to move a claim from self-declared to independently verified, with particular emphasis on product specificity, supporting documentation and claim authentication.

The four frameworks referenced above are not independent or competing benchmarks. They operate at different levels of the same overall assurance chain, and each builds on the one before it.

AS/NZS ISO 14021:2016 sits at the foundation. It defines what a recycled-content claim actually means, how pre-consumer and post-consumer material are distinguished, how a percentage is calculated, and what makes a self-declared environmental claim reliable rather than misleading. Every other framework in this assessment assumes a claim is already ISO 14021-compliant before asking further questions of it.

The National Framework for Recycled Content Traceability sits above this. It asks whether the information needed to trace an ISO 14021-compliant claim through the supply chain (where the material came from, how it was processed, who handled it) is being collected and shared at each stage, from material recovery through to final sale. It is a traceability maturity benchmark: it tells us whether the evidence trail exists, not whether any specific claim has been independently checked.

The NSW Recycled Content Reporting Guide applies a jurisdiction-specific reporting lens on top of this same foundation, translating recycled-content and traceability information into the categories, templates and disclosure formats expected of NSW Government procurement.

GECA's criteria for verification of recycled-content claims sit at the top of this chain. GECA is a product-specific assurance benchmark: it certifies that a particular claim, for a particular product, is accurate and evidenced including fitness-for-purpose considerations such as quality and safe handling of recyclate. Importantly, GECA's assurance approach is explicitly built on the traceability foundations set out in the National Framework, rather than replacing them.

5.1.5 Rating definitions

The four ratings provide the common assessment scale used throughout this report, particularly in the evidence-quality heatmap and the framework alignment summary, ensuring that each material stream is evaluated on a consistent basis. **Table 5.4** defines the criteria associated with each rating category.

Table 5.4 *Rating Definitions: Meaning of High, Medium, Low and Data Gap Ratings Used Throughout the Report*

Rating	Meaning
High	The claim is clear and supported by strong auditable evidence.
Medium	The claim is plausible and partly substantiated but contains limitations in product specificity, evidence completeness, or independent assurance.
Low	The value is estimated, the method or boundary is still being developed, or the evidence is not yet sufficient to substantiate the claim.
Data Gap	No project-specific evidence has been received for this material.

5.2 Baseline Development

This section establishes the recycled-content baseline for the six priority material streams included within the MOOV modular housing project. Recycled-content information was collected through a structured supplier questionnaire designed to capture both the reported recycled-content values and the supporting evidence underpinning those claims. Suppliers were asked to provide information on current recycled-content levels, the proportion of post-consumer and pre-consumer material, calculation methodologies, chain-of-custody arrangements, traceability systems, quality-assurance processes, self-assessed confidence levels, and future targets for increasing recycled content. Each declared figure has been checked for consistency with the reporting period it represents, the calculation methodology used, and the supporting evidence provided, using the same evidence-quality criteria (accuracy, adequacy, transparency and reliability) applied in the verification assessment set out in **Section 5.1.2**.

The resulting baseline provides the first consolidated snapshot of recycled-content performance across the assessed material streams and forms the foundation for the subsequent verification, alignment study, and benchmarking analyses presented under this chapter. **Table 5.5** summarises the recycled-content declarations submitted by suppliers, including the split between post-consumer and pre-consumer inputs and the basis on which each claim was calculated.

Table 5.5 *Declared Recycled Content by Material Stream*

Material stream	Declared recycled content (%)	Post-consumer (%)	Pre-consumer (%)	Reporting basis
Structural Steel	17.4% *	17.40%	0% **	FY, site average
Plasterboard	4.3% - 6.7%	All post-consumer	0%	Product-specific
Engineered wood (particleboard)	~40%	TBC	~40% (pre-consumer dominant)	Estimate, under validation
Composite decking	85%	35%	50%	Manufacturing-line average
Aluminium	0%	0%	0%	Confirmed Zero
Insulation Products	82% ***	63%	19%	FY 2025, Manufacturing-line average

** Adjusted from the 24% figure reported in BlueScope's supplier questionnaire; 17.4% is the figure published in BlueScope's Environmental Product Declaration, the only source confirmed as aligned with ISO 14021:2016.*

*** BlueScope's EPD reports a further 6.8% as recovered content (internal scrap reclaimed within its own steelmaking process), consistent with the additional 2% noted in the supplier questionnaire; both are classified separately from recycled content under ISO 14021:2016 and are excluded here.*

**** Knauf reported recycled contents of 77% (FY2024) and 66% (FY2023). The Environmental Product Declarations (EPDs) use FY2023 as the reference year.*

Composite decking and Insulation Products report the highest declared figures (85% and 82% respectively), engineered wood sits at an estimated 40%, structural steel and plasterboard sit in the low single-to-double digits reflecting their metal- and paper-based inputs, and aluminium remains at a confirmed 0% baseline. All figures are drawn from completed supplier questionnaires, cross-checked against item-level bill-of-materials data where available.

The reported recycled-content values vary considerably between material streams because of differences in manufacturing pathways, feedstock availability and product-performance requirements. Composite decking and glass-based insulation achieve substantially higher recycled-content levels than structural steel, plasterboard or aluminium within this project's own dataset, consistent with the general pattern that polymer-composite and glass-based products can more readily incorporate recycled inputs than primary metals or engineered boards, which remain constrained by process specifications, contamination risks and structural performance requirements.

The distinction between post-consumer and pre-consumer inputs is also important from a circular-economy perspective. ISO 14021:2016 distinguishes post-consumer material from manufacturing scrap and internal process recovery, recognising that post-consumer streams generally deliver stronger waste-diversion outcomes and require more mature collection and traceability systems.

Consistent with the National Framework for Recycled Content Traceability, assessment boundaries play a critical role in avoiding double counting and ensuring that recycled-content claims can be linked to a defined product system.

5.2.1 Indicative Dwelling-Level Recycled Content Baseline

Building on the six priority material streams assessed in the preceding sections, the bill of materials also enables the development of an indicative recycled-content baseline for the dwelling as a whole. Unlike the material-level assessment, which focused on evidence quality, verification status and framework alignment, this analysis considers all materials for which both weight and recycled-content information were available, regardless of whether they were subject to detailed verification. Based on the current bill of materials, 94.15% of the total dwelling weight has been mapped to a specific product, supplier and material quantity. The remaining 5.85% has not yet been linked to a specific product, supplier or weight and has therefore been excluded from the calculation. Importantly, these unmapped materials are treated as having an unknown recycled-content status rather than being assumed to contain no recycled content. Consequently, the results presented in this section should be interpreted as indicative and subject to refinement if additional product-level information becomes available and is incorporated into a future revision.

The dwelling-level baseline was calculated using a mass-weighted summation approach:

$$\text{Total Recycled Content (\%)} = \Sigma\,[\text{Weight}_i\,(\%) \times \text{Recycled Content_i}\,(\%)] \,/\, 100$$

where ***i*** represents each material included in the mapped bill of materials.

This methodology ensures that heavier materials contribute proportionally more to the overall result than lower-mass components. For materials where recycled content was reported as a range (for example, plasterboard (4.3–6.7%) and some self-declared fibre-cement products (0–4%)), the upper bound of the reported range was adopted in the calculation.

This approach was considered appropriate because the ranges reflect variation across suppliers' product portfolios rather than uncertainty regarding the recycled content of a specific product. Where the exact product supplied to MOOV could not be isolated within the range, the upper-bound value was treated as the most representative estimate of current achievable performance for that product family, consistent with the treatment applied elsewhere in this assessment for manufacturing-line and site-average claims. Accordingly, values derived from reported ranges should be interpreted as the upper end of suppliers' declared performance rather than as verified minimum recycled-content levels.

Applying this methodology across the mapped bill of materials produces the whole-dwelling result summarised in **Table 5.6**.

Table 5.6 *Dwelling-Level Recycled Content Baseline*

Metric	Total Recycled Content	Total Pre-consumer	Total Post-consumer
Weight (Kg)	2,652.90	1,385.20	1,267.70
% of total mapped dwelling	20.10%	10.50%	9.60%

The dwelling currently embodies an estimated 2,652.9 kg of recycled material, equivalent to **20.1% of total mapped dwelling weight.** The composition of this figure is broadly balanced between pre-consumer and post-consumer material, which account for 10.5% and 9.6% of mapped dwelling weight, respectively. However, this balance varies substantially between material streams. From a circular-economy perspective, this distinction is important because post-consumer content generally reflects more mature end-of-life collection, sorting and traceability systems, whereas pre-consumer content is more commonly associated with manufacturing offcuts, production residues and internal material recovery processes.

Figure 5.1 illustrates the relative contribution of each material stream to the dwelling's total recycled-content weight. Structural steel and engineered wood (particleboard) are the largest contributors, accounting for 23.1% and 22.2% of the total recycled-content mass, respectively. Insulation products contribute a further 20.9%, followed by composite decking (13.8%) and plasterboard (3.4%). The remaining 16.7% is associated with other materials outside the six priority streams.

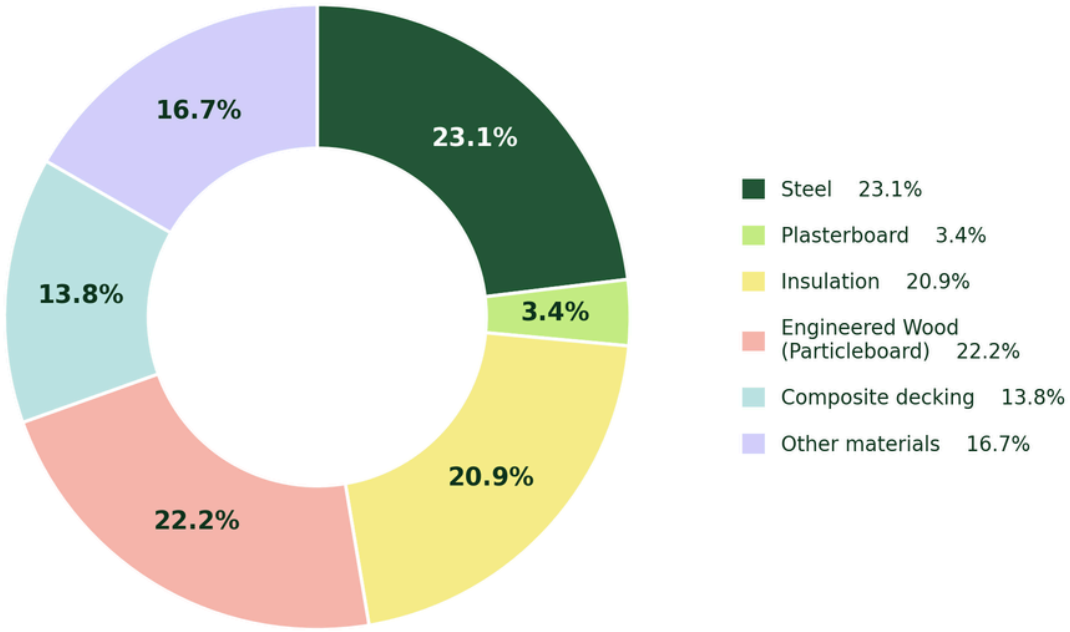


Figure 5.1 *Recycled-Content Contribution by Material Stream*

The figure demonstrates that recycled-content outcomes at the dwelling scale are influenced not only by the recycled-content percentage of individual products but also by their overall mass within the building. Materials with comparatively modest recycled-content claims can nevertheless make a substantial contribution to the whole-dwelling baseline when used in large quantities, while lightweight products with high recycled-content percentages may have only a limited effect on the overall result. Consequently, future efforts to increase recycled content across modular housing projects are likely to depend less on optimising minor material streams and more on improving the traceability and recycled-content performance of major structural and envelope materials.
For each material stream, the percentage contribution shown in **Figure 5.1** was calculated using:

Contribution (%) = Weight (%) × Recycled Content (%) ÷ 100

This calculation provides a consistent basis for comparing the relative influence of different materials on the dwelling-level baseline and supports the prioritisation of future interventions aimed at increasing recycled content across the MOOV supply chain.

5.3 Data Quality and Coverage Assessment

The evidence-quality assessment covers five material streams supplied to the MOOV project. Aluminium has been excluded, as no recycled-content claim or supporting documentation was provided. Each material stream was assessed against the four evidence-quality criteria outlined in **Section 5.1.2**, with scores based on the supporting evidence and documentation provided by suppliers rather than suppliers' self-assessed confidence ratings. **Figure 5.2** summarises the evidence-quality assessment across the material streams assessed.

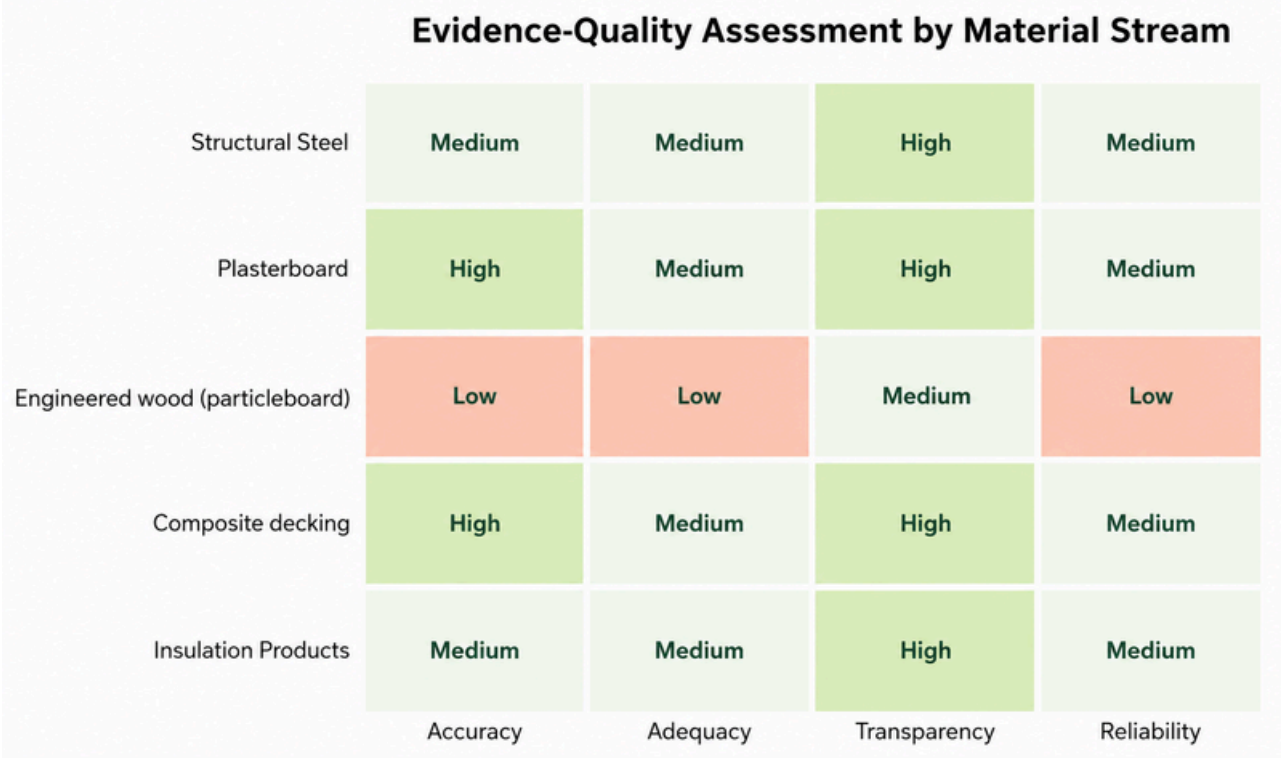


Figure 5.2 *Evidence-quality assessment by material stream*

Plasterboard is the only material stream for which the supplier reported genuinely product-specific recycled-content values. Knauf's figures of 6.7% for HEETROCK ONE 10 mm and 4.3% for both HEETROCK ONE 13 mm and WETSTOP 13 mm are calculated from the specific product recipes on a mass basis rather than being derived from manufacturing-line or site-wide averages. This distinguishes plasterboard from the other material streams and supports its High rating for accuracy. However, the supporting evidence was limited primarily to an internal calculation methodology, and the supplier separately indicated low alignment with the National Framework for Recycled Content Traceability. These limitations are reflected in the Medium ratings assigned for adequacy and reliability.

Composite decking and insulation products both reported recycled-content values based on manufacturing-line averages rather than product-specific calculations, although the strength of the supporting evidence differed between the two. ModWood advised that recycled content is determined from the ratio of raw material inputs to finished product outputs and noted that variation between products is minimal. The claim was supported by a comparatively extensive evidence package, including third-party verification, production records, purchasing records and documented internal procedures, which underpins its High ratings for accuracy and transparency. Knauf Insulation's glasswool products are similarly manufactured using a consistent process across all product lines, resulting in a common recycled-content figure supported by product life-cycle assessment data, annual manufacturing records and production data. Nevertheless, both streams received Medium ratings for adequacy and reliability because the reported values represent manufacturing-line averages rather than the specific products supplied to the project.

Structural steel was also assessed using a site-level average. BlueScope explained that the reported 24% recycled-content figure represents an average across the steel products manufactured at the Port Kembla Steelworks and does not indicate the recycled content of any individual product. The supplier provided a detailed explanation of the calculation methodology and demonstrated alignment with ISO 14021:2016 principles, supporting the High transparency rating. However, the absence of product-specific data and the limited evidence available to independently verify the traceability system resulted in Medium ratings for accuracy, adequacy and reliability.

Engineered wood (particleboard) recorded the lowest overall ratings across these criteria. Porta's reported figure is an estimated site average for the Oberon facility and was explicitly described as not representing the recycled content of individual products. The underlying methodology is still undergoing validation, with third-party verification expected within the next 6 to 12 months through the GECA Claims Authentication program. While the supplier provided useful information on the proposed calculation methodology and process flow, supporting documentation, including production records, chain-of-custody evidence and finalised calculation procedures, remains under development, limiting the extent to which the reported figure can currently be relied upon.

Across the five material streams, transparency was the strongest-performing criterion, with four streams receiving a High rating and engineered wood receiving a Medium rating. In all cases, suppliers were able to describe their calculation methods and explain the assumptions and limitations underpinning their claims. Accuracy, adequacy and reliability varied more significantly between materials and were influenced primarily by two factors: whether the recycled-content value represented a product-specific figure or a manufacturing-line or site-wide average, and the extent to which supporting documentation, production records, chain-of-custody evidence and independent verification had been established at the time of assessment. Overall, the findings suggest that suppliers are increasingly capable of calculating and reporting recycled-content figures, but that the systems required to support comprehensive product-level verification are still evolving. This pattern is consistent with the early-stage nature of the MOOV pilot and reinforces the value of establishing a more structured assurance framework to support future procurement and reporting requirements.

5.4 Verification of Recycled Content Claims

5.4.1 Material-by-material Verification

Each of the six material streams is reviewed below against the four assessment criteria in **Section 5.1.2**, with a declared figure, claim basis, current GECA status, main evidence gap and recommended action recorded for each.

Structural steel

Table 5.7 summarises the recycled-content declaration provided by BlueScope for structural steel.

Table 5.7 *BlueScope Structural Steel: Declared Figure, Claim Basis, GECA Status, Main Gap and Recommended Action*

Assessment Category	Finding
Declared figure	24% recycled content (18% post-consumer, 6% pre-consumer), FY, Port Kembla site average
Claim basis	Mass-and-yield calculation, ISO 14021:2016-aligned declaration
GECA verification status	Partially Substantiated
Status rationale	Methodology is mature and numerically credible, but not yet demonstrated as product- or delivery-specific to MOOV
Main gap	Product specificity and project-level traceability
Recommended action	Obtain a product-linked declaration, methodology note, and auditable mapping from the site-average figure to the product-level or downstream product-level figures

Structural steel was reported as a site-level average, and a review of published documentation revealed an important refinement to the recycled-content figure provided in BlueScope's supplier questionnaire. The questionnaire reported a recycled-content value of 24%, comprising 18% post-consumer and 6% pre-consumer content, based on a financial-year average across the Port Kembla Steelworks. BlueScope advised that the figure was calculated using a mass-and-yield methodology and aligned with ISO 14021:2016 principles. However, cross-referencing this value against BlueScope's EPDs (Please see **Appendix A** for EPD references) identified an important distinction between the figures reported in the questionnaire and those disclosed in independently published documentation.

BlueScope's EPDs state that "across the range of steel products manufactured by BlueScope in Australia, the average recycled content (according to recycled content categories defined in ISO 14021:2016) in the steel is 17.4%, which includes pre- and post-consumer recycled materials". The EPD further explains that scrap and iron-bearing materials generated and reclaimed from BlueScope's steelmaking, coating and painting operations represent an additional 6.8% recovered content that is not reported as recycled content under ISO 14021:2016.

Accordingly, this assessment adopts the 17.4% value reported in the EPD as the baseline figure for subsequent analysis and target setting, as it is the only value explicitly stated to align with the recycled-content categories defined in ISO 14021:2016. By contrast, the broader 24% value reported in the questionnaire appears to incorporate internally recovered materials generated within BlueScope's manufacturing operations, which ISO 14021:2016 distinguishes from recycled content and instead classifies as recovered content. The discrepancy illustrates one of the key findings of this study: although methodologies for calculating recycled content are generally mature, differences in terminology and reporting boundaries can materially influence the figures ultimately reported to customers and procurement bodies. This provides further support for why third-party verified recycled content numbers, based on clear definitions that are aligned with ISO 14021, are important to consistently measure outcomes and track changes over time.

Even after this adjustment, the declared recycled-content value remains broadly consistent with international benchmarks for steel produced via the integrated basic oxygen furnace (BF-BOF) route. Unlike electric arc furnace (EAF) steelmaking, which can accommodate substantially higher scrap fractions, integrated steel production remains dependent on virgin iron ore inputs to maintain process stability and product quality. The World Steel Association's Fact Sheet on Scrap notes that basic oxygen furnace steelmaking typically incorporates approximately 15–25% scrap, compared with much higher recycled inputs achievable through EAF production (Fact sheet on scrap, 2025). BlueScope's reported recycled-content figure therefore falls within the range expected for an integrated BF-BOF operation, where scrap utilisation is constrained by process heat balance, steel chemistry and product-performance requirements. As a result, recycled-content levels for structural steel vary significantly according to production technology, regional scrap availability and broader resource constraints within the steel sector.

The assessment found that BlueScope's methodology is relatively mature and transparent, supported by site-level mass-balance calculations and publicly available environmental declarations, which supports the High transparency rating assigned in **Figure 5.2**. However, the current evidence package does not demonstrate that the reported recycled-content figure can be directly linked to the specific steel products supplied to the MOOV project. The principal evidence gap therefore relates to product specificity and project-level traceability rather than the credibility of the underlying calculation methodology. This distinction is increasingly emphasised in the National Framework for Recycled Content Traceability and international procurement guidance, both of which place growing importance on linking facility-level averages to specific products and deliveries. Similar challenges have been observed internationally, where environmental reporting and recycled-content declarations for steel are commonly prepared at the plant, company or production-route level rather than for individual products, reflecting both the technical complexity of steelmaking and the practical limitations of product-level traceability.

On this basis, the structural steel claim has been assessed as **Partially Substantiated**, reflecting confidence in the underlying methodology while recognising the need for stronger evidence connecting the site-average figure to the steel products supplied to the MOOV project. Consequently, the Medium ratings for accuracy, adequacy and reliability have been retained.

Plasterboard

Table 5.8 presents the recycled-content information submitted for Knauf plasterboard products, together with an assessment of the claim basis, the current GECA verification status and the additional evidence required to improve confidence in the reported figures.
The recycled-content values reported for plasterboard are comparatively modest when assessed against other material streams. However, they are broadly consistent with Australian market conditions, where recycled gypsum availability and contamination risks constrain the incorporation of secondary materials. Unlike insulation and composite products, plasterboard manufacturers must maintain strict performance specifications relating to moisture resistance, fire performance and dimensional stability.

Australia's plasterboard recycling infrastructure remains comparatively early stage relative to other construction and demolition waste streams. Australia's construction and demolition industry generated 29 million tonnes of waste in 2020 to 21, representing 38% of all waste produced nationally, of which approximately 78% was recovered through reuse and recycling (Recycling Near You, 2025). This economy-wide figure is encouraging overall but does not isolate plasterboard-specific recovery rates, and gypsum board is understood to be recycled at a lower rate than more established construction and demolition streams such as concrete and metals. Dedicated plasterboard recycling capacity in Australia is also still consolidating around a small number of specialist operators. REGYP, described as Australia's largest plasterboard recycler, services major construction contractors including Boral, CSR, Knauf and BGC through a network of collection sites concentrated in Sydney, Melbourne, Brisbane, Canberra and Cowra (REGYP, 2024). This relatively concentrated recovery infrastructure, combined with contamination risks from co-mingled construction and demolition waste, currently limits the volume and consistency of recycled gypsum feedstock available to Australian manufacturers.

Knauf's calculation methodology, based on product recipes and mass-per-square-metre calculations, provides a stronger level of methodological confidence than some other streams assessed in this study. Nevertheless, the verification exercise identified gaps in documentary completeness, particularly regarding certification scope, source records and supporting evidence.

Table 5.8 *Knauf Plasterboard: Declared Figure, Claim Basis, GECA Status, Main Gap and Recommended Action*

Assessment Category	Finding
Declared figure	6.7% (HEETROCK® ONE 10mm) and 4.3% (HEETROCK® ONE 13mm, WETSTOP™ 13mm) — all post-consumer
Claim basis	Product recipe / mass-per-square-metre calculation, consistent across manufacturing sites
GECA verification status	Partially Substantiated
Status rationale	Calculation basis is stronger than documentary completeness; FSC Recycled certification is claimed but the certificate and its scope were not attached
Main gap	Documentary completeness
Recommended action	Submit final calculation support, source records, the FSC Recycled certificate, and an explicit claim-boundary statement

Engineered wood (particleboard)

Table 5.9 summarises Porta's estimated recycled-content claim for engineered wood products and outlines the validation process currently underway, the status assigned through this study and the key areas requiring further verification.

Porta reported an estimated recycled-content value of approximately 40%, derived predominantly from pre-consumer timber feedstocks recovered and reprocessed at its Oberon manufacturing facility. Unlike the other material streams assessed in this study, the supplier explicitly identified this figure as an estimate and advised that a formal validation and GECA Claims Authentication process is currently underway. This transparency strengthens the credibility of the submission, despite the absence of completed verification.

Table 5.9 *Porta Engineered Wood (Particleboard): Declared Figure, Claim Basis, GECA Status, Main Gap and Recommended Action*

Assessment Category	Finding
Declared figure	~40% recycled timber content (predominantly pre-consumer), Oberon site average, explicitly an estimate pending verification
Claim basis	Dry-mass calculation and material-flow diagram, 6–12 months validation process underway
GECA verification status	Under Verification
Status rationale	Supplier is transparent that the figure is not yet verified; traceability extends one step back only, to its immediate recycler
Main gap	Claim remains estimated; GECA Claims Authentication not yet complete
Recommended action	Retain 'under verification' status until GECA Claims Authentication is complete

Fi**gure 5.3** presents the process flow diagram provided by Porta to support the recycled-content calculation methodology used for particleboard production. The diagram maps the movement of shredded and unshredded timber feedstocks through key manufacturing stages, including storage, shredding, screening, drying and pressing, while also identifying moisture adjustments, process losses and internal rework streams.

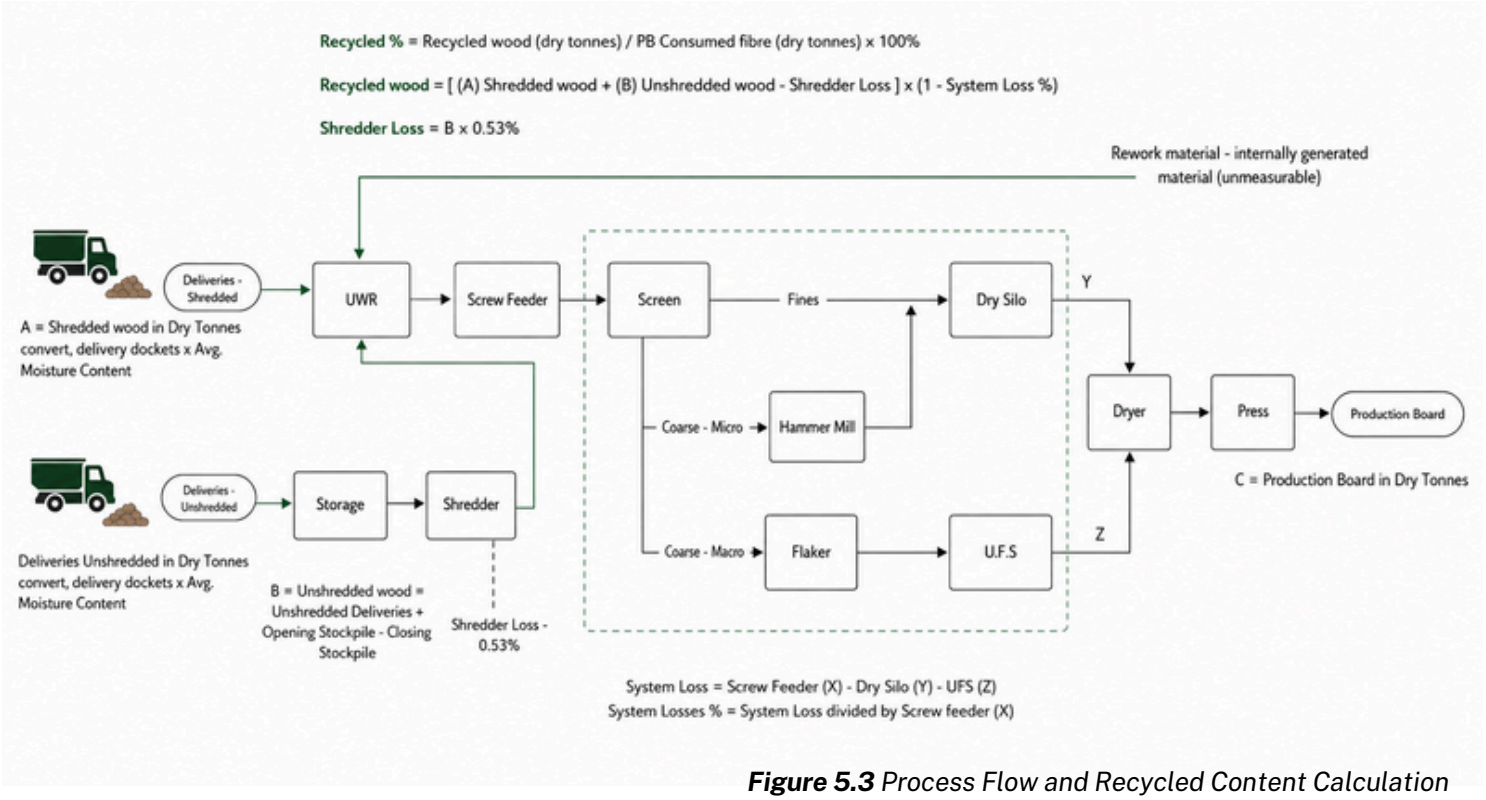


Figure 5.3 *Process Flow and Recycled Content Calculation Methodology for Porta Particleboard Production*

The process map demonstrates that Porta's methodology is based on a dry-mass balance approach. Incoming recycled timber volumes are adjusted using delivery dockets, average moisture-content data and stockpile records before being compared with the mass of finished production board generated. System losses are quantified across the screw feeder, dry silo and UFS stages, while internally generated rework material is identified separately and excluded from the measurable recycled-content calculation. This methodology is broadly consistent with internationally recognised mass-balance approaches used in timber-processing and composite-material industries to account for material losses throughout production.

The provision of detailed process-flow information indicates that the reported figure is grounded in operational manufacturing data rather than high-level assumptions. Nevertheless, the assessment found that traceability currently extends only one step upstream to Porta's immediate recycler, and the methodology has not yet been independently verified. Consequently, the recycled-content claim has been classified as **Under Verification**, reflecting the maturity of the calculation framework while recognising that the reported figure remains provisional until the GECA Claims Authentication process has been completed.

From a circular-economy perspective, engineered wood products are particularly well suited to incorporating pre-consumer timber residues, as manufacturing offcuts, sawdust and recovered fibre can often be reprocessed without significantly affecting product performance. Similar mass-balance approaches are widely used internationally to support chain-of-custody systems under schemes such as FSC Recycled and PEFC, although increasing emphasis is being placed on digital traceability and product-level verification to improve transparency across increasingly complex timber supply chains.

This distinction is important for procurement and reporting purposes. While the supplier has demonstrated a robust methodology for estimating recycled content, the present assessment does not yet provide sufficient evidence to substantiate the reported value as a verified claim. For this reason, the reported figure should continue to be treated as provisional until the validation process and supporting documentation have been finalised.

Composite Decking

Table 5.10 provides an overview of the recycled-content claim reported for composite decking, including the manufacturing methodology, supporting evidence package and the remaining documentation required to fully substantiate the claim.

Table 5.10 *ModWood Composite Decking: Declared Figure, Claim Basis, GECA Status, Main Gap and Recommended Action*

Assessment Category	Finding
Declared figure	85% recycled content (35% post-consumer, 50% pre-consumer)
Claim basis	Manufacturing-line mass balance, reconciled monthly against stock-take, independent verification cited
GECA verification status	Partially Substantiated
Status rationale	The strongest evidence package in the dataset, but the final documentary chain (the verification record itself, and its scope) still needs to be reviewed
Main gap	Documentary linkage between the cited verification and the specific MOOV-supplied product
Recommended action	Complete the verification record and confirm its scope covers the product and reporting period supplied to MOOV

Composite decking demonstrates the highest declared recycled-content proportion of all material streams assessed in this study. The reported 85% recycled content reflects the inherent suitability of wood-polymer composite systems for incorporating recovered plastics and timber residues without compromising product performance.

The supplier's methodology represents one of the most mature evidence packages received during the verification exercise. Monthly stock reconciliation, manufacturing-line mass balance calculations and references to independent verification collectively provide a stronger degree of assurance than was available for several other materials.

Internationally, wood-plastic composites are widely recognised as an important circular-economy application because they create long-term demand for difficult-to-recycle plastics and low-value timber by-products (Ellen MacArthur Foundation, 2023). This is reflected in the products of several international manufacturers. Trex, one of the largest composite decking producers globally, reports having recycled over 5.5 billion pounds of plastic film into decking products and sources all wood content from reclaimed material rather than virgin timber (Trex, n.d.). Similarly, TimberTech reports recycled content levels of approximately 65 to 85% across its product range, depending on the specific line (TimberTech, n.d.). ModWood's declared 85% recycled content therefore sits at the upper end of, but within, the range reported by established international composite decking manufacturers, indicating the figure is technically plausible and consistent with global trends in composite construction materials rather than being an outlying claim.

Despite this strength, the assessment identified one remaining evidence gap. The verification documentation itself was not provided alongside the questionnaire response. The supplier indicated that the underlying verification was conducted by a third-party certification body, and that confidentiality considerations relating to that arrangement currently limit the disclosure of the full verification record to this assessment. Closing this final documentary gap, by attaching the verification record and confirming its scope covers the specific product and reporting period supplied to MOOV, would significantly strengthen confidence in the claim and would represent a comparatively low-effort step given the maturity of the underlying evidence base.

Aluminium

Table 5.11 summarises the supplier declaration received for aluminium products supplied to MOOV, highlighting the current baseline position, associated verification status and opportunities identified for future recycled-content uptake. Unlike the other material streams, aluminium establishes a confirmed baseline of zero recycled content for the products supplied to MOOV. Although recycled aluminium can substantially reduce energy consumption and greenhouse gas emissions relative to primary production, the current supply arrangement relies entirely on virgin aluminium feedstock.

From a verification perspective, the absence of recycled content simplifies assessment and reduces the risk of overstating environmental benefits. However, the supplier identified potential future pathways for introducing closed-loop recycled aluminium systems capable of incorporating recycled content of approximately 20%. International experience demonstrates that aluminium recycling systems depend heavily on the availability of segregated scrap streams and the existence of dedicated collection and remanufacturing infrastructure. For this reason, any future recycled-content targets should be treated as aspirational until supported by evidence and implemented supply-chain arrangements.

Assessment Category	Finding
Declared figure	0% recycled content (current supply from virgin log)
Claim basis	N/A
GECA verification status	Supplier-Confirmed Baseline
Status rationale	N/A
Main gap	No current gap; the risk is premature uplift to the aspirational future figure
Recommended action	Document the described 20% closed-loop pathway separately as a future opportunity, not a current claim

Table 5.11 *National Aluminium – Aluminium: Declared Figure, Claim Basis, GECA Status, Main Gap and Recommended Action*

Knauf insulation

Table 5.12 presents the recycled-content information provided by Knauf for insulation products, including the reported recycled-content values across multiple reporting years, the methodology used to derive the claim, the current verification status and the actions required to strengthen alignment with emerging traceability frameworks.

Table 5.12 *Knauf Insulation: Declared Figure, Claim Basis, GECA Status, Main Gap and Recommended Action*

Assessment Category	Finding
Declared figure	82% recycled content (2025); 77% (2024); 65% (2023, the reference year used in Knauf's EPDs). Breakdown: 63% post-consumer, 19% pre-consumer, 0% unknown
Claim basis	Manufacturing-line average (consistent across all products); calculated on a dry mass basis in accordance with ISO 14021; recycled glass and other feedstock melted and converted to glasswool fibres via the ECOSE® process; supported by product LCA, internal calculation methodology, annual manufacturing data, production records and supplier declarations; mass-balance chain of custody, with feedstock sourced from within Australia and Asia
GECA verification status	Partially Substantiated
Status rationale	The figure is a manufacturing-line average rather than a product-specific figure, and no chain-of-custody documentation has been provided
Main gap	Manufacturing-line (not product-specific) figure; National Framework alignment; chain-of-custody documentation
Recommended action	Request confirmation of whether recycled content varies across the specific batts supplied to MOOV; obtain chain-of-custody documentation; and work with Knauf to close the self-identified National Framework alignment gap

Knauf insulation reports one of the highest recycled-content figures within the study, increasing from 65% in FY2023 to 82% in FY2025. This upward trend reflects improvements in recycled-glass sourcing, including a purpose-built processing facility developed to handle recycled glass collected through Queensland's Containers for Change programme.

The evidence package supporting the claim is among the most comprehensive submitted, comprising life-cycle assessment documentation, annual manufacturing records, production data, supplier declarations and an internally developed calculation methodology aligned with ISO 14021:2016. The supplier also reported high confidence in the accuracy of the recycled-content calculation and in feedstock traceability.

Nevertheless, the assessment identified an important distinction between manufacturing-line averages and product-specific claims. The recycled-content figure applies across the manufacturing line rather than to individual insulation batches or deliveries supplied to MOOV, a limitation the supplier itself acknowledged. Knauf's self-assessment also identified low confidence in alignment with the National Framework for Recycled Content Traceability, despite the strength of the underlying calculation methodology. This distinction, between a mature calculation methodology and comparatively weaker traceability documentation, is consistent with the pattern observed across most material streams in this study.

Glasswool insulation is internationally recognised as one of the more circular construction materials, since it can incorporate substantial quantities of recycled glass cullet while continuing to meet thermal and fire-performance requirements. Eurima, the European Insulation Manufacturers Association, reports that mineral wool producers across Europe are already using up to 60% recycled materials in their products (Eurima, n.d.), while glass mineral wool environmental product declarations indicate that recycled cullet can constitute up to 80% of glass mineral wool's composition. Knauf's reported 82% figure for the MOOV project therefore sits at or above the upper end of published international benchmarks, reinforcing that the calculation methodology and feedstock sourcing described in the supplier's response are technically credible, even though product-level traceability remains the primary evidence gap.

5.4.2 Project-level Framework Readiness

To complement the material-by-material assessment presented in the previous sections, the recycled-content evidence submitted for the six priority material streams was evaluated against the four frameworks outlined in **Section 5.1.4**: AS/NZS ISO 14021:2016, the National Framework for Recycled Content Traceability, the NSW Recycled Content Reporting Guide and GECA's criteria for verification of recycled-content claims. Rather than reassessing the validity of individual supplier claims, this analysis considers the extent to which the overall evidence base supporting the MOOV project is prepared for different levels of reporting, verification and future procurement requirements.

A key scoping finding is that none of the six reportable MOOV construction materials currently fall within the product categories listed in Table 1 of the NSW Recycled Content Reporting Guide, which focuses primarily on furniture and fit-outs, ICT hardware, medical equipment, office supplies and textiles. Consequently, the mandatory preferencing and reporting obligations introduced under NSW Government Action 22 do not currently apply to the materials assessed in this study. Instead, recycled-content requirements for the construction sector are expected to be addressed through the proposed Protection of the Environment Policy for Sustainable Construction, which remains under development. In this context, the NSW Guide has been used throughout this study as a reference point for emerging best practice rather than as a compliance requirement.

Table 5.13 summarises the relative readiness of each material stream against the four assessment frameworks. The ratings should not be interpreted as measures of legal compliance or environmental performance; rather, they indicate the extent to which the evidence currently available would support different levels of claim substantiation, supply-chain traceability and future third-party verification.

Table 5.13 *Framework Readiness Summary for Each Material Stream*

Material stream	ISO 14021 alignment	National Traceability Framework alignment	NSW Reporting Guide alignment	GECA criteria readiness
Structural Steel	High	Medium	Not applicable	Low
Plasterboard	High	Low	Not applicable	Medium
Engineered wood (particleboard)	Medium	Low	Not applicable	Low
Composite decking	High	Medium	Not applicable	Medium
Insulation Products	High	Medium	Not applicable	Medium

At a project level, the assessment indicates that supplier capability to calculate and report recycled-content figures is generally more mature than the systems used to verify and trace those claims through the supply chain. Alignment with AS/NZS ISO 14021:2016 is comparatively strong across most material streams, reflecting the fact that suppliers were generally able to define claim boundaries, distinguish between pre-consumer and post-consumer content, and explain the methodologies used to calculate recycled-content percentages.

Structural steel, plasterboard, composite decking and insulation products demonstrate high alignment with ISO 14021, while engineered wood (particleboard) demonstrates medium alignment due to the provisional nature of the current claim and the ongoing verification process.

By contrast, alignment with the National Framework for Recycled Content Traceability is more mixed, and tracks closely with the maturity of each supplier's underlying record-keeping systems rather than the strength of the recycled-content figure itself. Structural steel, composite decking and insulation products all demonstrate medium alignment: each is supported by formal, documented systems (such as production records, life-cycle assessment documentation, purchasing records or comparable evidence) that monitor recycled inputs over time, even though none currently provides product-specific evidence capable of linking recycled-content calculations directly to the materials supplied to the MOOV project. Plasterboard and engineered wood (particleboard) demonstrate lower alignment, reflecting more limited chain-of-custody documentation and, in the case of particleboard, a calculation methodology still undergoing validation.

Readiness against GECA's criteria for verification of recycled-content claims broadly follows this same pattern, since GECA's assurance approach is itself built on the traceability foundations set out in the National Framework, rather than sitting apart from it. Composite decking and insulation products both achieve medium GECA readiness, consistent with their medium Framework alignment and comparatively mature evidence packages. Engineered wood (particleboard) remains lower, reflecting the least mature evidence base identified in this study, with chain-of-custody documentation still under development. Structural steel also scores lower despite its medium Framework alignment: recycled-content calculations are undertaken at the site level and cannot currently be attributed to specific products or production batches, which limits readiness for independent, product-level verification. Plasterboard is the one exception to this general pattern, achieving medium GECA readiness despite lower Framework alignment — its declared figures are the only genuinely product-specific values identified in this assessment, calculated from specific product recipes on a mass basis rather than a manufacturing-line or site-wide average, even though chain-of-custody documentation remains an outstanding gap here as well. Aluminium has not been assessed against any framework because no recycled-content claim or supporting documentation was submitted.

Taken together, these findings suggest that the MOOV supply chain has established a credible foundation for transparent recycled-content reporting, provided that important caveats regarding data quality, claim boundaries and verification status are clearly communicated. More broadly, the assessment reinforces a challenge identified throughout both the literature review and supplier engagement activities: the principal barrier to robust recycled-content assurance is rarely the calculation of recycled-content percentages themselves, but rather the ability to demonstrate a clear and auditable link between manufacturing-level averages and the specific products supplied to an individual project. This challenge is particularly relevant to modular housing, where procurement frequently relies on complex supply chains and high-volume manufactured products. As expectations around traceability, digital product information and embodied-carbon reporting continue to evolve, strengthening these evidence pathways will become increasingly important.

Viewed in this context, the MOOV project represents an important pilot for improving recycled-content assurance within modular housing procurement. Although the current evidence base does not support comprehensive verification across all material streams, it provides valuable insights into the maturity of existing supplier systems and highlights practical opportunities to strengthen future procurement requirements. For Homes NSW and future modular housing programs, the results point to the need for more third-party verification of results against a fixed standard to boost the quality of the data and processes, and provide a platform for consistent measurement of change over time. Failing that, consistent supplier questionnaires, standardised reporting templates and clearer expectations regarding record retention and product-level traceability can all help in the short-term, but will likely not drive outcomes or provide the confidence that would come with certification.

5.5 Benchmark Target Setting

5.5.1 Suppliers Benchmark Target Setting

Suppliers were asked to indicate current recycled content, a high-confidence value achievable now, a 3 to 5-year intermediate target, and a longer-term aspirational target. **Table 5.14** below shows the provided benchmark trajectory for the material streams selected for this project.

Table 5.14 *Benchmark Trajectory by Material Stream: Current, Achievable-Now, 3–5 Year Target and Aspirational Recycled-Content Figures (provided by suppliers)*

Material stream	Current	Achievable now	3–5yr target	Aspirational
Structural Steel	24% (*17% as per ISO 14021*)	not provided	not provided	not provided
Plasterboard	4.3–6.7%	no change expected	no change expected	no change expected
Engineered wood (particleboard)	~40%	70%	70–90%	>90%
Composite decking	85%	85%	85%	99%
Aluminum	0%	0%	20%	20%
Insulation Products	66–82%	82%	82%	82%

The results of the survey indicate that suppliers are confident that several material streams are already performing at relatively high levels, with limited scope for further improvement under current market conditions. Composite decking currently achieves 85% recycled content and is expected to maintain this level in the near and medium term, although an aspirational target of 99% demonstrates significant long-term circularity potential. Engineered wood (particleboard) presents the most substantial opportunity for improvement, increasing from approximately 40% currently to 70% achievable now and potentially exceeding 90% over the longer term, reflecting strong prospects for greater recycled feedstock integration. Aluminium currently contains no recycled content, and no immediate improvement is considered achievable. Suppliers identified a pathway to reach 20% recycled content within the next three to five years, suggesting future supply chain or manufacturing developments. Structural steel currently contains 24% recycled content, although no forward-looking targets were provided, limiting assessment of its future improvement potential. BlueScope steel and Knauf plasterboard did not provide targets beyond their current recycled content figures, indicating either uncertainty regarding future improvements or an expectation that current performance will remain unchanged. Similarly, while Knauf insulation provided responses for each target horizon, it expects recycled content to remain constant at 82%, suggesting that current performance represents the practical limit under existing technology, supply availability, or manufacturing processes. Overall, the findings suggest that while some material streams are approaching maturity, significant gains remain possible in selected products, particularly engineered wood and, to a lesser extent, aluminium, which are likely to be the primary drivers of future recycled content improvements within the Homes NSW project.

This self-reported data also highlights that most of the material streams are not publicly committing themselves to ambitious growth in their sector. To get more significant change, additional market or regulatory forces may be required.

5.5.2 International Modular Project Benchmark and Industry Benchmark per Material Stream

A review of international modular housing projects found that publicly available reporting of material-specific recycled content remains limited. Most modular housing case studies report embodied carbon, waste reduction, or circular design outcomes rather than recycled-content percentages for individual material streams. Consequently, this assessment combines both International Modular Project Benchmarks and Industry Benchmarks to provide a more comprehensive and practical basis for target setting.

Together, these two benchmark sources provide complementary insights: modular project benchmarks demonstrate practical application and circularity outcomes within the built environment, while industry benchmarks establish achievable recycled-content performance based on currently available products and manufacturing practices. Using both perspectives enables Homes NSW to develop realistic yet ambitious recycled-content targets that are informed by both proven modular construction practices and global material industry leadership.

Structural steel

Structural steel represents one of the world's most mature circular material markets because steel can be recycled indefinitely without loss of mechanical properties. The examples in **Table 5.15** demonstrate that significantly higher recycled-content structural steel is already commercially available, although procurement remains dependent on regional scrap availability, manufacturing route and product specification.

Table 5.15 *Benchmark Assessment – Structural Steel*

Metrics	Structural Steel	Sources
International Benchmark	Conventional BF-BOF steel: **20–30%** recycled content. Electric Arc Furnace (EAF): **60–90%** recycled content routinely achieved. Leading manufacturers **exceed 90%.**	*World Steel Association (2023); ResponsibleSteel (n.d.); Nucor Corporation (2025a, 2025b)*
Typical Post-Consumer Share	**18%** in conventional integrated steel. **80%** input in EAF production (scraps).	*World Steel Association (2023); ResponsibleSteel (n.d.)*
Primary Post-Consumer Source	Structural steel recovered from demolished buildings, bridges, industrial facilities and other end-of-life infrastructure.	*SteelConstruction.info (n.d.)*
Primary Pre-Consumer Source	Manufacturing offcuts, fabrication scrap, rolling mill returns and steel processing waste recycled directly into new steel production.	*World Steel Association (n.d.)*
End-of-Life Recyclability	Structural steel is **100% recyclable** without loss of mechanical properties. Recovery rates exceed **95%**, with UK studies reporting **98–99% recovery** during demolition.	*SteelConstruction.info (n.d.); Build Using Steel (n.d.)*
Modular Construction Fit	Primary structural material for volumetric modules, light-gauge framing, transport chassis, floor systems and inter-module connections. Easily prefabricated, transported, disassembled and recycled.	*Kings Research (n.d.); Modular Building Institute (2023) Institute:*
International Modular Project Examples	**Mākhers Plug-In Pods (USA):** ~4 tonnes of recycled shipping-container steel reused per dwelling. **Tiny House Shadow (Finland):** recycled structural steel incorporated into modular tiny-house construction. Another Circularity example (reuse): **Nam Cheong 220 (Hong Kong MiC):** >95% structural steel reused through relocation of complete modules	*Hong Kong CIC (n.d.); Red & Black (n.d.); Tiny House Shadow (n.d.)*
Indicative Procurement Target	**Short-term:** ≥30% verified recycled content **3–5 years:** ≥50% through increased EAF procurement (sourcing more EAF-based steel) **Long-term:** ≥60% (or higher where EAF supply is available).	*World Steel Association (2023); ResponsibleSteel (n.d.); Nucor Corporation (2025a)*

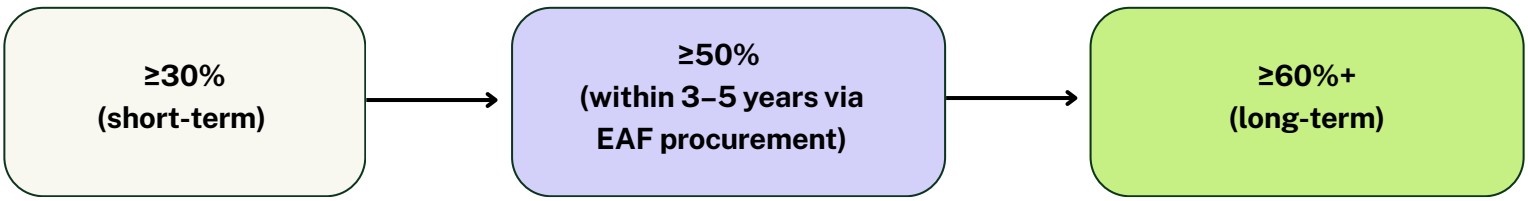
Australia's current supplier benchmark of approximately 24% recycled content is broadly consistent with conventional integrated steelmaking. However, substantially higher recycled-content products are already commercially available domestically: InfraBuild's Environmental Product Declarations report recycled-content levels of 86.1–95.0% across reinforcing, merchant and structural steel manufactured via EAF technology (InfraBuild, 2024).

The composition of recycled content is a key differentiator. The current benchmark comprises approximately 18% post-consumer and 6% pre-consumer material, whereas EAF steelmaking typically relies on scrap feedstocks exceeding 80% (World Steel Association, 2023). Post-consumer material is generally regarded as representing a stronger circular-economy outcome than internally recovered manufacturing waste.

Structural steel also performs exceptionally well on end-of-life resource recovery. The World Steel Association identifies steel as the world's most recycled engineering material, capable of being recycled indefinitely without loss of performance. UK data corroborates this, reporting structural steel recovery rates of 98–99% during demolition (SteelConstruction.info, n.d.; Build Using Steel, n.d.). This performance is particularly relevant to modular construction, where steel's strength, dimensional stability and transportability support its use in volumetric modules, chassis and inter-module connections (Modular Building Institute, 2023). International examples reinforce this: the Nam Cheong 220 MiC project in Hong Kong was designed for future relocation, retaining over 95% of its structural steel system (Hong Kong CIC, n.d.); the Mākhers Plug-In Pods concept in the United States repurposes approximately four tonnes of shipping-container steel per dwelling (Red & Black, n.d.); and Finland's Tiny House Shadow project incorporates reclaimed structural steel into prefabricated housing (Tiny House Shadow, n.d.).

The principal global constraint on increasing recycled content is scrap availability rather than technology. Steel demand currently exceeds the volume of end-of-life scrap entering the market (World Steel Association, n.d.). The OECD identifies expanded scrap utilisation as a key decarbonisation pathway, while the World Economic Forum estimates recycled scrap could supply approximately 44% of global steel demand by 2050 (World Economic Forum, 2023), suggesting recycled-content availability will improve over the life of future Homes NSW housing programs.

RECOMMENDED PROCUREMENT PATHWAY:



Claims should be supported by product-specific EPDs (BlueScope, n.d.), ISO 14021-compliant declarations, and ResponsibleSteel-certified supply chains where possible.

Plasterboard

Compared with other material streams, plasterboard currently exhibits relatively low recycled-content levels due to challenges associated with recovering clean gypsum feedstock. The Homes NSW supplier baseline of 4.3–6.7% recycled content aligns with the upper end of the current Australian market. Internationally, substantially higher recycled gypsum incorporation has already been demonstrated through closed-loop recycling systems. Eurogypsum reports successful manufacture of plasterboard containing up to 30% recycled gypsum through the Gypsum-to-Gypsum programme, while manufacturer-led innovation has produced products containing recycled contents exceeding 90% and, more recently, plasterboard manufactured using 100% recycled gypsum. These examples represent international best practice but are not yet reflective of mainstream Australian supply chains. The plasterboard benchmark assessment is summarised in **Table 5.16**.

Table 5.16 *Benchmark Assessment – Plasterboard*

Metrics	Plasterboard	Sources
International Benchmark	Typical Australian: **2–6%** Australian opportunity: **up to 20%** EU Gypsum-to-Gypsum: **up to 30%** USG EcoSmart Firecode X: **up to 94.6%** Saint-Gobain Infinaé 100: **100% recycled gypsum core**	*Bradfield Development Authority (2025)* *Eurogypsum (n.d.)* *USG Corporation (n.d.)* *Saint-Gobain/British Gypsum (n.d.)*
Typical Post-Consumer Share	100% of reported recycled content is post-consumer; recycled gypsum from C&D waste, recycled paper liners from post-consumer newspaper/cardboard	*Gyprock (n.d.)* *Eurogypsum (n.d.)*
Primary Post-Consumer Source	Recovered from refurbishments, strip-outs, renovations and demolition; requires contamination control	*REGYP (n.d.)* *Eurogypsum (n.d.)*
Primary Pre-Consumer Source	Manufacturing scrap, board trimming, rejected board, paper offcuts, production residues	*Gypsum Association (n.d.)*
End-of-Life Recyclability	Gypsum 100% recyclable where contamination controlled; Australian infrastructure focused on clean source-separated streams	*Eurogypsum (n.d.); Gypsum Association (n.d.); REGYP (n.d.)*
Modular Construction Fit	Factory production enables improved offcut recovery, source separation and take-back logistics vs. conventional construction	*McKinsey & Company (2020); Modular Building Institute (2023)*
International Modular Project Examples	Few modular projects publicly disclose recycled-content %; EU Gypsum-to-Gypsum demonstrates closed-loop recovery **up to 30%**	*Eurogypsum (n.d.)* *Gypsum Association (n.d.)*
Indicative Procurement Target	**Short-term:** ≥10% **3–5 years:** ≥15% **Long-term:** ≥20%. Stretch: up to 30%	*Bradfield Development Authority (2025); Eurogypsum (n.d.)* *Gyprock (n.d.)*

Plasterboard is a priority material for the Homes NSW program given its repeated use across internal linings and its concentrated manufacturer base, where EPDs and certification pathways are already established. The Homes NSW supplier questionnaire identifies Knauf's SHEETROCK® ONE 10mm, SHEETROCK® ONE 13mm and WETSTOP™ 13mm products at 6.7%, 4.3% and 4.3% recycled content respectively, all post-consumer, calculated via ISO 14021-aligned mass-balance. The supplier indicates no improvement is expected across any time horizon, so this baseline should be read as a fixed current position rather than a trajectory.

This baseline sits within the range identified by the Bradfield Development Authority (2025), which records typical Australian plasterboard at 2–6% recycled content against an Australian opportunity benchmark of up to 20%. Bradfield also flags an important claim-boundary issue: recycled paper liner content is already mature and standard practice and should not be conflated with recycled gypsum core content when reporting whole-board percentages.

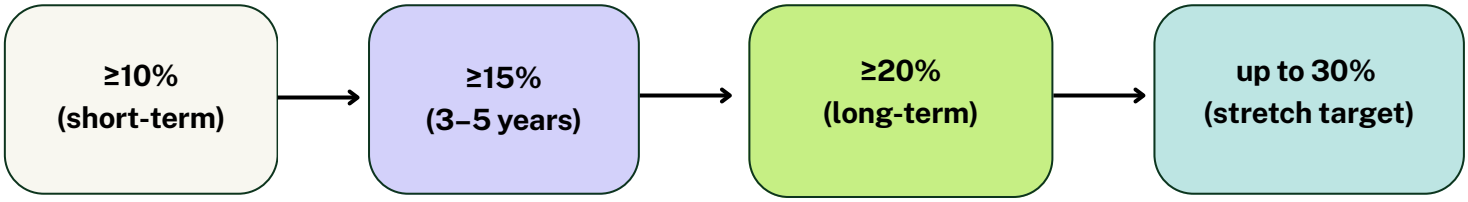
Australian evidence supports this distinction. Knauf (n.d.) reports its Australian boards use 100% recycled paper liners with locally sourced gypsum, and CSR Gyprock (n.d.) reports a comparable liner benchmark alongside recycling over 95% of manufacturing waste. Gyprock HD demonstrates a higher whole-board product already available locally, formulated to 10% recycled content (Gyprock, n.d.), though specification equivalence for Homes NSW would need confirmation.

The principal Australian constraint is feedstock supply rather than material recyclability. Bradfield (2025) identifies contamination risk (notably asbestos) as a barrier to recovering plasterboard into new board production, with REGYP (n.d.) — Australia's largest plasterboard recycler — applying strict contamination controls (up to 1% allowance) across its collection network. Existing take-back schemes provide a foundation for uplift: DCCEEW (n.d.) reports CSR Gyprock's take-back scheme diverting roughly 1,400 tonnes annually from landfill, though only accepting clean, uncontaminated offcuts. Knauf has similarly reported downcycling 12,000 tonnes of manufacturing scrap into agricultural and engineering products (Architecture & Design, n.d.).

International benchmarks show materially higher recycled gypsum content is achievable with mature collection systems. Eurogypsum (n.d.) reports the EU Gypsum-to-Gypsum project achieving up to 30% recycled gypsum content, contingent on deconstruction practices, landfill policy and end-of-waste status. USG's EcoSmart Firecode X reaches up to 94.6% recycled content where regionally available (USG Corporation, n.d.), and Saint-Gobain's Gyproc SoundBloc Infinaé 100 — the first UK board made from 100% recycled gypsum — followed an earlier French product with at least 50% recycled content (Saint-Gobain/British Gypsum, n.d.). However, even within the EU, uptake lags technical potential: despite over 2 million tonnes of recycled gypsum being available annually, only around 600,000 tonnes were used in new plasterboard production by 2019 (Jiménez-Rivero and García-Navarro, cited in Waste Transport Solutions, 2025) — indicating the Australian gap reflects a global pattern of underutilised recycling capacity rather than a uniquely local shortfall.

The strongest near-term opportunity for Homes NSW lies in factory-based offcut segregation and take-back rather than immediate substitution to high-recycled-content board. The Gypsum Association (n.d.) notes construction generates gypsum scrap equal to roughly 12% of board used, which is well-suited to source separation in a controlled factory setting. Modular production (McKinsey & Company, 2020) offers more consistent conditions for this than dispersed conventional sites, provided offcuts are segregated by type, kept dry, and linked to a take-back arrangement.

RECOMMENDED PROCUREMENT PATHWAY:



where verified closed-loop gypsum recovery is demonstrated.

Engineered wood (particleboard)

Table 5.17 sets out the benchmark assessment for particleboard.

***Table 5.17** Benchmark Assessment – Engineered wood (particleboard)*

Metrics	Engineered wood (particleboard)	Sources
Australian Market Benchmark	**80–85%** appropriate benchmark (40% industrial residue + 45% post-consumer) D&R Henderson: **75% pre-consumer + 10–20% post-consumer**, or ~**83% total (74% post-industrial + 9% post-consumer)**	*Bradfield Development Authority (2025); Recycling Near You (n.d.); reDirect Recycling (n.d.)*
Scenario / Emerging Market Benchmark	**90–95%** plausible where sorting/cleaning is mature. Kronospan Chirk: 90% recycled content (up from 60% in 2016). Kronospan UK EPD: 95.6% secondary material inputs	*Woodknowledge Wales (n.d.); Kronospan (n.d.)*
International Best Practice Benchmark	≥95% verified secondary input as strongest EPD-backed benchmark; 100% recycled wood as aspirational ceiling	*Kronospan (n.d.) - First particleboard panel made from 100% recycled wood*
Indicative Procurement Target	**Short-term:** 65–80% **3–5 years:** 80–90% **Long-term:** ≥95% where verified supply chains exist.	*Based on supplier baseline and international benchmarks above*

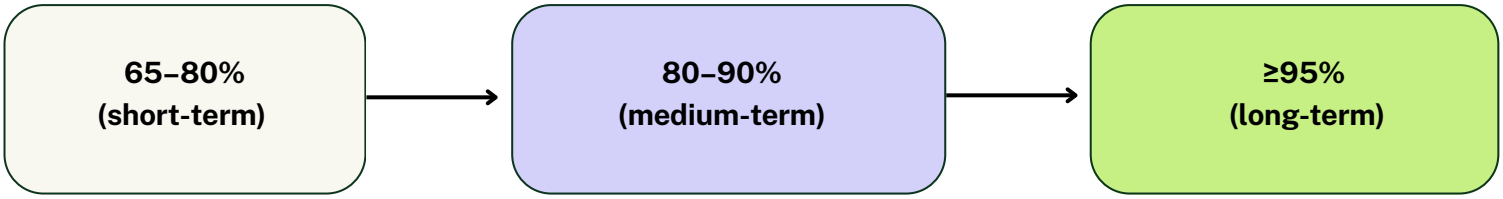
Porta's 40% baseline demonstrates recycled timber is already being incorporated at the Oberon site. However, international comparators show materially higher recycled input is achievable. The Composite Panel Association's North American particleboard EPD reports 92.44% wood residues by composition, though this is a residue-based disclosure rather than an ISO 14021 recycled-content claim (Composite Panel Association, n.d.). EGGER reports 66% of group wood inputs come from sawmill by-products or recycling (EGGER, n.d.), while Uniboard's Canadian particleboard reaches 83.7–86.5% pre-consumer content, albeit with no post-consumer share (Uniboard, n.d.). Pfleiderer's imported product reaches 85% total recycled/residue content, combining 40% industrial residue and 45% post-consumer material (Pfleiderer, n.d.).

The strongest examples come from Kronospan. Its Chirk, UK facility produces construction products with 90% recycled content, having increased post-consumer waste use from 60% in 2016 (Woodknowledge Wales, n.d.), and its UK melamine-faced particleboard EPD reports 95.6% secondary material inputs under third-party verification (ISO 14025/EN 15804+A2/ISO 21930) (Kronospan, n.d.). Kronospan's Luxembourg facility has gone further, announcing the first particleboard panel made entirely from 100% recycled wood (Kronospan, n.d.), though this should be read as a best-practice signal rather than a near-term Australian procurement assumption.

Domestically, Bradfield Development Authority (2025) identifies an Australian opportunity benchmark of up to 80%, citing D&R Henderson's 75% pre-consumer plus 10–20% post-consumer content. Recycling Near You similarly reports Australian particleboard reaching approximately 83% total recycled material (74% post-industrial, 9% post-consumer) (Recycling Near You, n.d.), while reDirect Recycling describes a closed-loop pathway in which particleboard offcuts are diverted and re-manufactured into new board (reDirect Recycling, n.d.).

The main opportunity is shifting from provisional site-average reporting to verified dry-mass, product-mapped reporting. Porta identified government procurement requirements and customer demand as key drivers for increasing recycled content, indicating Homes NSW tender requirements could accelerate uplift. The main constraints are cost, product performance and quality consistency rather than feedstock availability — Porta ranked feedstock as the least significant constraint and confirmed sufficient recycled wood supply exists to support planned increases.

RECOMMENDED PROCUREMENT PATHWAY:



where verified circular supply chains are commercially available

Composite Decking

The benchmark position for composite decking is captured in **Table 5.18** below.

Table 5.18 *Benchmark Assessment – Composite Decking*

Metrics	Composite Decking	Sources
Australian Market Benchmark	**85–90%** as current best practice ModWood ~90% recycled/reclaimed; Ekodeck up to 90% Replas minimum 85% recycled plastic	*ModWood (n.d.);* *Ekodeck (n.d.);* *Replas (n.d.)*
Scenario / Emerging Market Benchmark	**90–95%** where EPDs and feedstock verification exist Trex 95%; MoistureShield 95%; EnviroBuild Hyperion ≥87% (EPD-verified); TimberTech 60–85%	*Trex (n.d.);* *MoistureShield (n.d.);* *EnviroBuild (n.d.);* *TimberTech (n.d.)*
International Best Practice Benchmark	**≥95%** where backed by third-party EPD Trex: 95% recycled sawdust and polyethylene. MoistureShield: 95%	*Trex (n.d.);* *MoistureShield (n.d.)*
Indicative Procurement Target	**Minimum:** ≥85% total, ≥35% post-consumer **Preferred:** ≥90% **Stretch:** ≥95%	*Based on supplier baseline and benchmarks above*

Composite decking is already one of the strongest recycled-content streams in the Homes NSW program. The ModWood baseline of 85% (35% post-consumer, 50% pre-consumer) should be treated as the minimum "no backwards step" procurement threshold (ModWood Sustainability, n.d.).

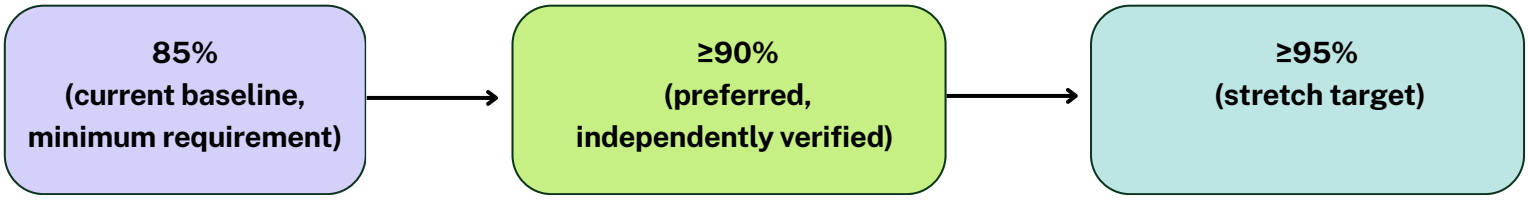
Relative to the Australian market, ModWood performs strongly. Public disclosures indicate ModWood products contain approximately 90% recycled or reclaimed material, including recycled milk bottles and reclaimed pine dust. Comparable products report similar performance: Ekodeck contains up to 90% reclaimed and recycled material (Ekodeck, n.d.), and Replas products contain a minimum of 85% recycled plastic (Replas, n.d.). This places ModWood at the upper end of disclosed Australian composite decking products, indicating the Homes NSW baseline is aligned with leading domestic performance rather than an entry-level benchmark.

Internationally, ModWood's 85% remains competitive but sits below several market leaders. Trex reports approximately 95% recycled content (50% recycled wood fibre and 45% recycled polyethylene), supported by a product-specific EPD (Trex, n.d.).

MoistureShield similarly reports 95% recycled content and EnviroBuild's Hyperion Explorer decking declares a minimum 87% recycled content through an independently verified EPD (EnviroBuild, n.d.). These examples show recycled-content levels above 90% are achievable in mature international markets with established recovered-polymer supply chains and product-specific verification.

The international market is more mature in its evidence base than the current project-specific position: leading manufacturers such as Trex and EnviroBuild support claims through product-level EPDs and detailed disclosures, while ModWood's evidence currently relies on manufacturing-line-average reporting. Nonetheless, the 85% Homes NSW baseline already exceeds many construction-product recycled-content benchmarks generally.

RECOMMENDED PROCUREMENT PATHWAY:



where EPD-backed products and verified supply chains are commercially available

Aluminium

Table 5.19 sets out the benchmark assessment for aluminium extrusions.

***Table 5.19** Benchmark Assessment – Aluminium*

Metrics	Aluminium	Sources
Australian Market Benchmark	**20%** recycled content via Rio Tinto/Sims Metal closed-loop scheme Current Australian market capability: **Up to 30%** recycled content for aluminium extrusions where product-specific verification is available.	*Bradfield Development Authority (2025)*
International Best Practice Benchmark	Hydro CIRCAL 75R: **minimum 75%** post-consumer recycled aluminium, DNV-verified with batch traceability. Hydro CIRCAL 100R: 100% post-consumer scrap (specialist/stretch benchmark) 50–60% recycled content as a future scenario (US and Europe)	*Hydro CIRCAL (2026), Bradfield Development Authority (2025), US Aluminum Association (2025)*
Indicative Procurement Target	**Short-term:** 20% **Medium-term:** 30% (Australian market benchmark) **Long-term:** 75% where internationally verified circular aluminium supply chains become commercially available.	*Bradfield Development Authority (2025)* *Hydro CIRCAL (2026)*

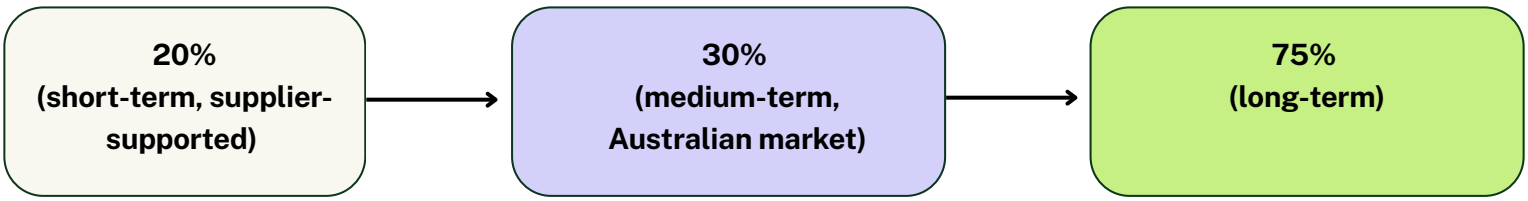
Aluminium is more constrained than structural steel and plasterboard because Australia's domestic recycled-aluminium market remains underdeveloped. The Australian Aluminium Council/L.E.K. report notes Australia retains a vertically integrated aluminium sector — bauxite mining, alumina refining, primary smelting and extrusion — but limited domestic remelt and recycling capability, exporting around 95% of aluminium scrap (approximately 440kt annually, including 43kt of pre-consumer extrusion scrap) (Australian Aluminium Council/L.E.K., 2026).

The most viable near-term Australian pathway is closed-loop recycling of clean pre-consumer extrusion scrap into billet. The L.E.K. report identifies a Capral/Rio Tinto/Sims Metal pathway in which extrusion scrap is remelted at Boyne Smelters and returned as billet with at least 20% recycled content, and Capral's 2025 announcement confirms an initial 1,000 tonnes of aluminium at minimum 20% recycled content for local extrusion (Capral, 2025). This supports 20% as the most defensible near-term benchmark, provided the supplier can demonstrate participation and chain-of-custody — noted as currently confirmed for Capral's Bremer Park supply chain specifically, with National Aluminium's participation still to be confirmed. The 30% benchmark should be read as an Australian opportunity ceiling rather than a confirmed target. Bradfield Development Authority (2025) states aluminium is typically procured at 0% recycled content in Australia, with an opportunity of up to 30% in domestically extruded products, citing Capral and G. James as extruders advertising this level and Tomago's commitment to 550 tonnes/year of pre-consumer scrap for remelt.

International benchmarks illustrate materially higher achievable levels but on a different basis. Hydro CIRCAL is independently verified by DNV at a minimum 75% post-consumer scrap content with batch-level traceability, and Hydro CIRCAL 100R demonstrates production entirely from post-consumer scrap (Hydro CIRCAL, 2026). These should be treated as a high-end specialist benchmark rather than a near-term Australian target, since the Australian pathway is currently built on pre-consumer scrap rather than the verified post-consumer streams underpinning the Hydro benchmark.

Recycled-content claims must also be tied to a precise claim boundary — billet, extrusion, fabricated frame or whole window/door assembly are not interchangeable, and the current 0% baseline applies to the aluminium extrusion only, not the full assembly including glass, gaskets, hardware and coatings.

RECOMMENDED PROCUREMENT PATHWAY:



where internationally verified circular aluminium supply chains become commercially available

Future benchmarks should require billet supplier declarations, batch/alloy traceability, a claim-boundary statement, and ASI Chain of Custody or equivalent evidence before acceptance.

Insulation

Insulation products represent one of the strongest-performing recycled-content material streams assessed for the Homes NSW modular housing program. Unlike structural steel, aluminium and plasterboard, where significant gaps remain between current supplier performance and international best practice, Knauf's current supplier baseline already aligns with the upper end of internationally reported recycled-content levels for commercial glass wool insulation.

The figures in **Table 5.20** demonstrate that recycled-content levels above 80% are already well established across mature insulation markets through the use of recycled glass cullet, recovered paper fibre and closed-loop manufacturing systems (Knauf Insulation, n.d.; Eurima, n.d.; NuWool, n.d.; Saint-Gobain Isover, n.d.).

Table 5.20 *Benchmark Assessment – Insulation*

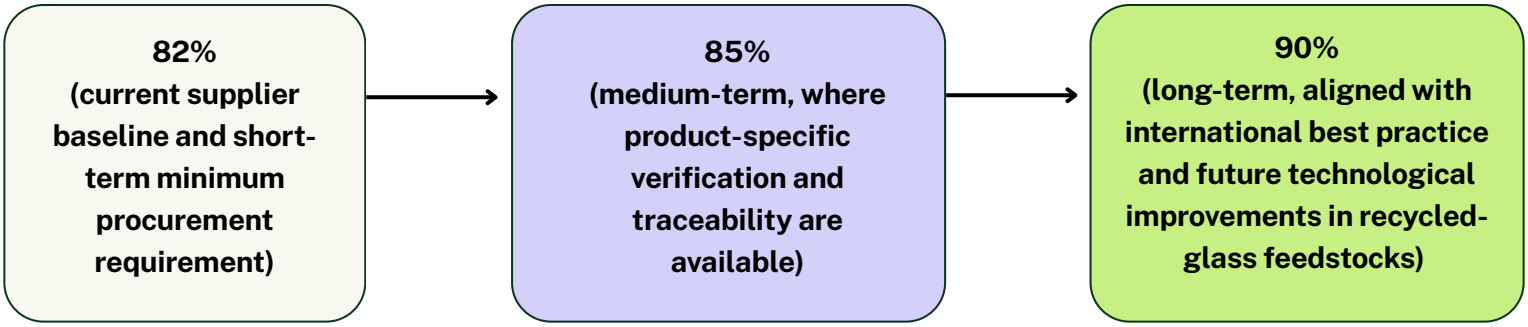
Metrics	Insulation	Sources
Australian Market Benchmark	Glass wool insulation: **60–85% recycled content** Cellulose insulation: **83–87% recycled content**	*Knauf Insulation (n.d.)* *Eurima (n.d.)*
International Market Benchmark	Leading commercial insulation products routinely exceed **80% recycled content** through recycled glass and recycled paper feedstocks	*CIMA (2026); NuWool (n.d.)* *Saint-Gobain Isover (n.d.)*
Typical Post-Consumer Share	Glass wool: **50–80% post-consumer recycled glass** Cellulose insulation is almost entirely manufactured from post-consumer newspaper and paper fibre.	*Eurima (n.d.); CIMA (2026); NuWool (n.d.); Knauf Insulation (n.d.), Saint-Gobain Isover (n.d.); NAIMA (n.d.)*
Primary Post-Consumer Source	Glass wool: Recycled community and curbside glass, including household glass containers and construction and demolition waste Cellulose insulation: Recovered newspapers and paper products.	*Eurima (n.d.); CIMA (2026); NuWool (n.d.); NAIMA (n.d.)*
Primary Pre-Consumer Source	Internal production off-cuts and manufacturing process scrap from both glass wool cutting/trimming and customer/construction-site off-cuts recovered and fed back into insulation manufacture through closed-loop and take-back recycling schemes and industrial glass recovered directly into insulation manufacture.	*Knauf Insulation (n.d.); Saint-Gobain Isover (n.d.)*

Metrics	Insulation	Sources
End-of-Life Recyclability	Glass wool can be recycled into new insulation where collection systems exist. Mineral wool recycling schemes are expanding internationally although collection infrastructure remains less mature than steel or aluminium.	*Eurima (n.d.); Saint-Gobain Isover (n.d.)*
International Modular Project Examples	**Brighton Waste House (UK)** used denim jeans, alongside other waste materials (DVDs, video cassettes, toothbrushes), as wall-cavity insulation in a circular construction demonstration project.	*Waste House (2018)*
Indicative Procurement Target	**Minimum Procurement Requirement:** ≥80% **Preferred Target:** ≥85% where product-specific verification is available **Future Stretch Target:** ≥90% (subject to future technology and feedstock availability)	Based on Knauf supplier baseline and international benchmarks from Knauf Insulation, Eurima and Nu-Wool.

Unlike other material streams, insulation is approaching a practical technical limit for recycled-content incorporation. Consequently, future improvements are more likely to depend on technological innovation than procurement changes alone.

Insulation products are well suited to modular construction because factory-based installation reduces waste, improves quality control and supports efficient material management. International examples, including the Legacy Living Lab (Australia) and Brighton Waste House (UK), demonstrate the successful use of high recycled-content insulation within prefabricated and circular building systems.

RECOMMENDED PROCUREMENT PATHWAY:



5.6 Assessment Findings

5.6.1 Summary of Verification Outcomes

Across the six material streams assessed, data availability was not the same as verification readiness: every responding supplier could provide a recycled-content value or confirm a zero-content baseline, but only some could provide a clear product mapping, reporting period, calculation method and traceability description. The most common weaknesses were incomplete pre/post-consumer breakdowns, reliance on site or manufacturing averages rather than product-specific values, limited independent assurance, and documentation not yet explicitly aligned with the National Framework. Supplier self-confidence was generally higher than the evidence-based assessment reached in this report; this is a normal market pattern rather than a sign of bad faith and reflects that internal sustainability figures are not automatically project-assurance-ready. Coverage is now available for all six identified material streams from completed supplier questionnaires, though manufacturing-line-average figures and National Framework alignment still need to be strengthened for several streams, most notably engineered wood and insulation.

5.6.2 Key Findings: Dwelling-Level Recycled Content Performance

The dwelling currently embodies an estimated 20.1% recycled content by weight (2,652.9 kg across 94.15% of mapped dwelling weight), split roughly evenly between pre-consumer (10.5%) and post-consumer (9.6%) material. This is a reasonable starting baseline for a first-generation modular pilot, but it rests on an uneven foundation: structural steel and engineered wood (particleboard) together account for 45.3% of the dwelling's total recycled-content weight, and neither claim is fully verified at the product level. Steel's figure is a manufacturing-site average; particleboard's is an estimate still 6–12 months from third-party authentication.

Only one of the six assessed material streams (plasterboard) reports a genuinely product-specific recycled-content figure. Every other stream (steel, engineered wood, composite decking, insulation) reports a manufacturing-line, site, or company-wide average. This is not a supplier failing so much as an industry-wide pattern: none of the suppliers in this study currently maintain systems capable of certifying recycled content at the level of an individual delivery or batch supplied to a specific project.

Calculation methodology is consistently more mature than traceability. Across all six streams, suppliers could explain how their recycled-content figures were calculated, several with reference to ISO 14021:2016. Far fewer could demonstrate a documented chain of custody linking that calculation to the specific products delivered to MOOV. This is the single most consistent gap in the dataset, and it recurs regardless of material type, claimed percentage, or company size.

Recycled-content availability is structurally different across material types, not just supplier-dependent. Aluminium's confirmed 0% baseline reflects an industry-wide constraint (scrap segregation and remelting infrastructure not yet established for the extruders and regions supplying this project) rather than a lack of supplier effort and BlueScope's steel findings show that even mature, EPD-verified industries face a genuine technical ceiling on scrap incorporation (BF-BOF steelmaking), meaning higher recycled content is not simply an adoption question for every material.

5.6.3 Recycled-Content Benchmark Findings

The benchmark assessment across the six priority material streams reveals a consistent pattern: current Homes NSW supplier baselines are broadly aligned with, or in some cases lead, Australian market practice, but sit well below global best practice for the majority of materials. The gap is most pronounced for aluminium and plasterboard, moderate for structural steel and engineered wood, and largely closed for composite decking and insulation. **Table 5.21** summarises these findings across all six materials.

Table 5.21 *Benchmark Assessment*

Material	Current	Global Best Practice	Gap	Procurement Priority
Structural Steel	24% (*17%*)	60–90%	▲ High	• Transition toward EAF steel • Specify minimum technology-aligned recycled content • Require product-specific EPDs/Claims
Plasterboard	4–7%	20–30%	▲ Very High	• Require separate liner vs. gypsum-core disclosure • prioritise suppliers with verified take-back schemes • Stage targets as supply matures
Engineered Wood (Particleboard)	40%	70–90%	▲ Medium	• Increase recycled fibre requirements while maintaining product performance • Require product-specific verified claims • Embed targets in tenders
Composite Decking	85%	95–99%	▼ Low	• Maintain current performance • Adopt market-leading and verified products above 90% where available
Aluminium	0%	30–75%	▲ Very High	• Introduce recycled billet specifications in procurement and ASI Chain of Custody • Target 20–30% near-term minimum
Insulation	82%	85–90%	▼ Low	• Maintain high recycled-content products • Favour verified EPDs/Claims

Materials with the greatest improvement opportunity

Aluminium and plasterboard represent the two most significant gaps identified in the assessment. Aluminium's 0% current baseline reflects a single, unverified supply pathway rather than a lack of market capability. The Australian closed-loop pathway already supports 20–30% recycled content through existing Capral/Rio Tinto/Sims Metal arrangements, while international producers such as Hydro reach up to 75% post-consumer content, meaning even the near-term domestic opportunity would represent a substantial improvement over the current zero baseline. Plasterboard's gap is driven less by technical limitations than by feedstock availability and contamination-control constraints in the Australian recovery system; the global benchmark of 20–30% is achievable but depends on maturing local collection and take-back infrastructure rather than any barrier to gypsum recyclability itself.

Materials with a moderate gap

Structural steel and engineered wood both show meaningful headroom, but for different reasons. Steel's gap is primarily a function of production route — EAF steelmaking already delivers 60–90% recycled content internationally, and Australian EAF products (e.g. InfraBuild) already demonstrate 86–95%, meaning the constraint is procurement specification rather than technical or supply-side capability. Particleboard's gap is narrower in absolute terms but is constrained by cost, product performance requirements and quality consistency, rather than feedstock scarcity. Porta has confirmed sufficient recycled wood feedstock is available to support planned increases.

Materials already performing well

Composite decking and insulation are the standout performers, with current baselines close to or within range of global best practice. For these materials, the priority shifts from uplift to protection: locking in current performance as a "no backwards step" minimum, favouring verified EPD-backed products where commercially available, and avoiding downward drift in future procurement rounds.

Overall procurement implication

The findings support a differentiated, risk-weighted procurement strategy rather than a single uniform recycled-content target across all materials. High-gap materials (aluminium, plasterboard) warrant staged targets with evidence gates, given the relative immaturity of verified supply, though aluminium's wider best-practice range (30–75%) indicates a credible near-term domestic pathway exists alongside the higher international ceiling; moderate-gap materials (steel, particleboard) can support more assertive near-term specification given existing market capability; and low-gap materials (decking, insulation) should be protected through minimum-performance clauses rather than pushed toward further uplift where the marginal benefit is limited and current products already perform close to international best practice.

5.6.4 Implications for Future Modular Projects and Supplier Engagement

Build evidence and verification requirements into procurement up front, not reviewing after the fact

This project's core difficulty was retrofitting a verification exercise onto claims and documentation that suppliers had not been asked to prepare with project-level traceability in mind. Homes NSW should specify recycled-content evidence requirements (methodology disclosure, product-specificity, chain-of-custody documentation) as a condition of the RFT or supply contract for future modular projects, not as a downstream data request.

Track two dwelling-level or program-level recycled-content KPIs

Homes NSW should track (1) the dwelling-level recycled-content percentage, and (2) a weighted confidence score reflecting how much of that figure is independently verified versus supplier self-declared. This project's usable output is the 20.1% dwelling-level figure alongside its confidence range. Reporting both together prevents an unverified claim from carrying the same authority as a certified one and gives Homes NSW a clear signal of progress as suppliers move toward independent verification (e.g. via GECA) over time; hence, the confidence score should rise even where the content percentage stays flat.

Mandate third-party verified evidence for both carbon and recycled content, phased by material maturity

Homes NSW should require third-party verified carbon figures (EPD, PCF, or another ISO 14067-aligned pathway) and recycled-content claims verified against the National Framework for all priority materials. For steel and insulation, where EPD and calculation infrastructure is already mature, this should apply immediately, with the remaining gap addressed through traceability and contracting fixes linking site averages to specific deliveries. For engineered wood and other timber-based products, where verification infrastructure is still developing, this should apply on a defined transition timeline tied to authentication milestones (e.g. GECA), rather than as an immediate compliance requirement.

Track "product-specific vs average" as its own disclosure field, separate from the recycled-content percentage itself

Homes NSW found that a single, transparent figure (e.g. Plasterboard's 6.7%) can be lower than a higher but non-specific figure (e.g. Steel's 17.4% site average) — treating the two as equivalent understates the value of product-specific reporting to future evaluators. As full alignment with the National Framework becomes the norm, this additional field should no longer be needed.

Expect variable ceilings by material, and set targets accordingly

BlueScope's own submission demonstrates that steel's recycled content is constrained by process chemistry and heat balance, not just sourcing choices; global scrap availability is a further constraint. Homes NSW should calibrate aspirational recycled-content targets per material type against realistic, internationally benchmarked ceilings (as this report did for plasterboard, insulation, and composite decking), rather than applying a single blanket target uniformly across all material categories in future modular projects.

Use this project's supplier responses as a reference dataset for future supplier engagement

BlueScope, Knauf, ModWood, and Porta's responses collectively give Homes NSW a working sense of what "good" evidence looks like (ModWood and Knauf) versus what's still developing (Porta), which can inform supplier pre-qualification or evaluation criteria for future modular programs, independent of this project's own outcome.

6 Embodied Carbon Assessment

6.1 Upfront Embodied Carbon (A1-A3) Baseline Assessment

6.1.1 System Boundary Definition

The upfront embodied-carbon assessment presented in this report adopts a cradle-to-gate system boundary encompassing life-cycle stages A1–A3 in accordance with EN 15978 and EN 15804. As summarised in **Figure 6.1**, the assessment includes raw-material extraction and processing (A1), transport of materials to manufacturing facilities (A2), and the manufacture of building components and modules (A3), while excluding transport to site, construction activities, operational impacts and end-of-life scenarios.

Restricting the analysis to stages A1–A3 allows direct comparison between the baseline dwelling and future scenarios incorporating higher recycled-content materials. This boundary is particularly relevant to modular construction, where material specification and manufacturing decisions exert their greatest influence before installation. It also aligns with emerging procurement frameworks, including the Commonwealth Environmentally Sustainable Procurement Policy, which increasingly emphasises the selection of low-carbon and resource-efficient materials.

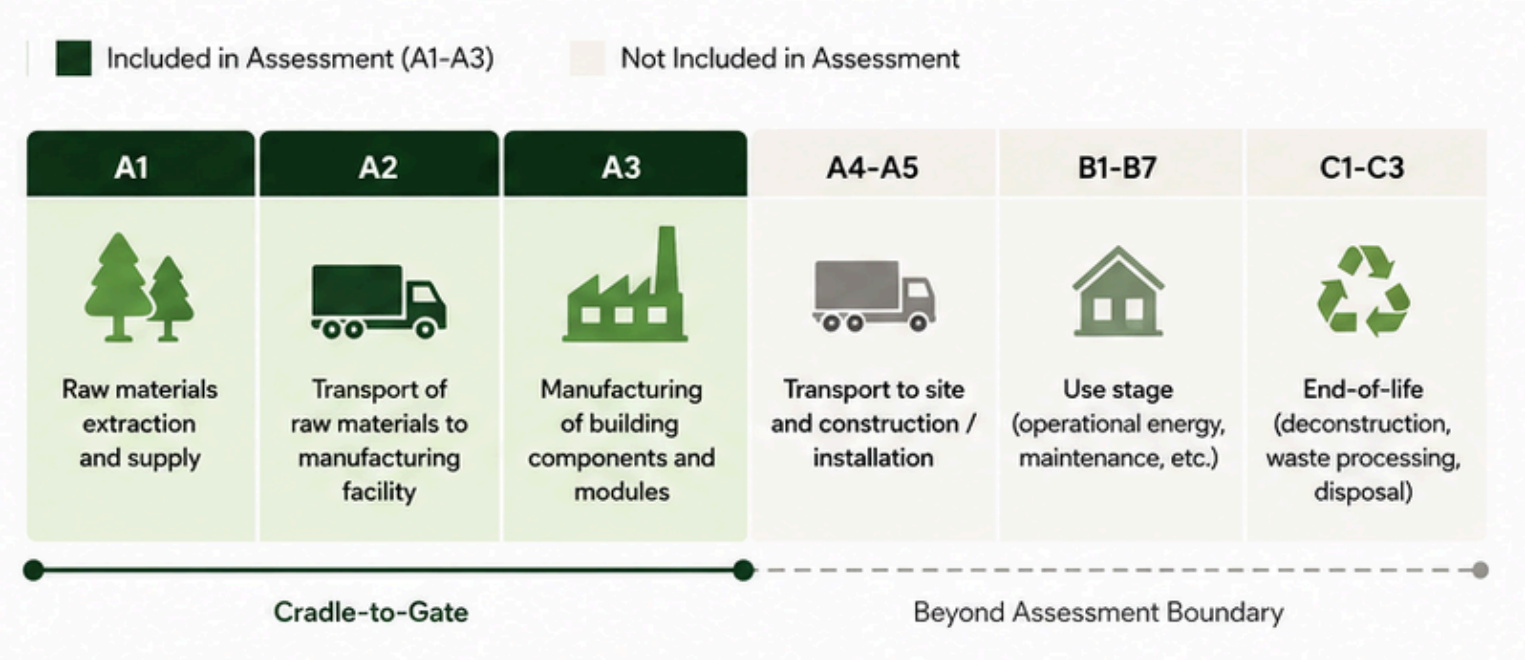


Figure 6.1 *Life-Cycle Stages Included in the Embodied Carbon Assessment Boundary*

6.1.2 Methodology

The baseline assessment for the MOOV modular dwelling establishes the reference point against which increased recycled content scenarios will be evaluated.

Following are the key information used in assessing the baseline carbon footprint of the MOOV modular home project (weighing approximately 14 tonnes with 77m2 floor area):

- Bill of quantities (BoQ) listing material quantities, brand/model of building materials provided by MOOV – Please see **Table 4.1** and **Appendix D** for more details.
- Product-specific carbon footprint from Environmental Product Declaration (EPD) - where applicable. Referenced EPDs are listed in **Appendix A**.
- Energy consumption (Electricity and LPG) between 1 May 2025-30 April 2026:
- Electricity: 21,750kWh
- LPG (bottled gas) for forklifts: 432 litres
- Estimated production waste of 2-5% depending on material type at MOOV's facility in Gosford NSW
- Estimated transport distance between source of material and MOOV factory at Gosford NSW
- Where product-specific carbon footprint is not available, generic carbon footprint (from background database such as AusLCI, ecoinvent, NABERS Emission Factor data) is used.

The above information is inputted into Rebuilt's Product Carbon Footprint (PCF) platform to assess the cradle-to-gate (Stages A1-A3) carbon footprint of the MOOV modular home before it is delivered to site.

6.1.3 Baseline assessment results

The baseline assessment estimates that the MOOV modular dwelling embodies approximately 29,439 $kgCO_2e$, equivalent to 382.3 $kgCO_2e/m^2$ of floor area. Of the total A1–A3 footprint, raw materials account for approximately 91%, with the remaining 9% attributable to on-site manufacturing energy (electricity and LPG) at MOOV's Gosford facility, underscoring that material specification rather than factory energy use is the primary lever for reducing MOOV's upfront carbon footprint. **Figure 6.2** presents the contribution of each material stream to the overall A1–A3 footprint.

To contextualise this result, it is compared against published Australian and international embodied carbon benchmarks. Direct comparison is imperfect, as these studies vary in life cycle scope (A1–A3 versus A1–A5), floor area basis (Gross Floor Area (GFA) versus Conditioned Floor Area (CFA)), and building elements included, but provide some rough guidance of performance.

The GBCA's Our Homes Weigh a Tonne (2025) is the most current Australian benchmark, modelling a typical 234 m^2 detached house at 1000–1160 $KgCO_2e/m^2$ of conditioned floor area (up to 1,290 $kgCO_2e/m^2$ in some regions), or approximately 185,000 $KgCO_2e$ per home.

This is a broader A1–A5 scope that also captures external works, landscaping, solar PV and full services, elements outside MOOV's A1–A3 boundary. MOOV's 382.3 $kgCO_2e/m^2$ sits well below this benchmark, consistent with its narrower life cycle and element scope.

Against smaller, more comparable Australian case studies, the result reads differently. Illankoon et al. (2023) measured three 200–240 m^2 Sydney homes at 193–233 $kgCO_2e/m^2$ (A1–A5, GFA basis), a lower figure than MOOV's A1–A3-only result.

Against Slattery's national benchmarking data (2024), the average upfront embodied carbon for new-build Australian residential construction in 2024/2025 is 639 $kgCO_2e/m^2$ (GFA basis). MOOV's baseline A1–A3 result of 382.3 $kgCO_2e/m^2$ sits well below this figure, noting Slattery's residential average reflects the broader A1–A5 scope (including transport to site and construction/installation activities), whereas MOOV's assessment is restricted to A1–A3, so the two are not strictly like-for-like and the true gap on a matched cradle-to-gate basis would likely be narrower.

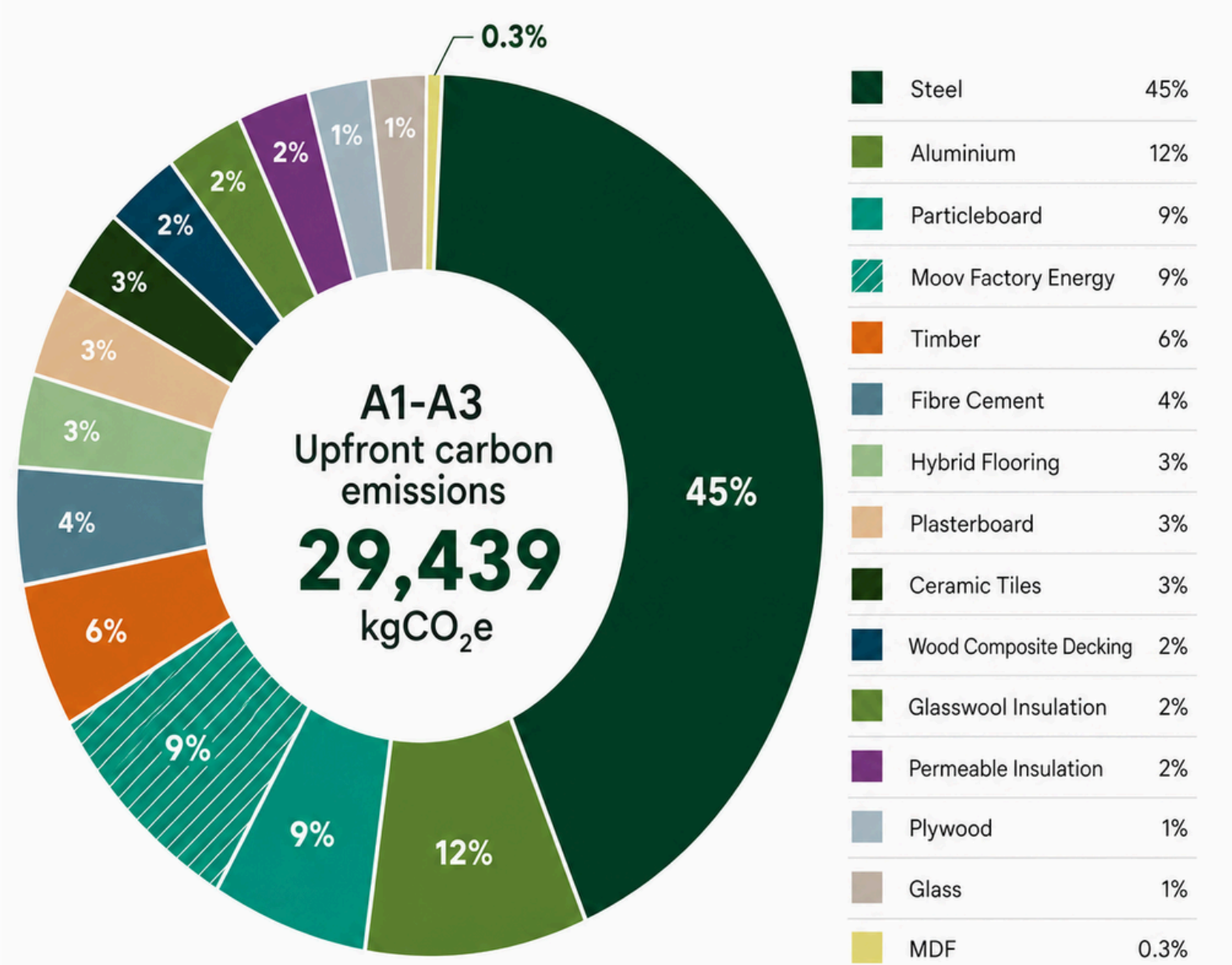
Internationally, a 2025 systematic review of modular and prefabricated construction (O'Hegarty et al., Buildings & Cities, 82 case comparisons) found intensities ranging from approximately 140 to 860 or more $kgCO_2e/m^2$, depending on structural material, with no consistent embodied carbon advantage over traditional construction. MOOV falls within this range.

A further useful comparator is a recent whole-life LCA of a modular light-gauge steel frame (LGSF) social housing unit at Brooklands, Wirral Waters, UK (Nangir et al., 2026). That 99 m^2 terraced dwelling reports an A1–A3 embodied carbon of 34,816 $kgCO_2e$, equivalent to 351.68 $kgCO_2e/m^2$. This is close to, though somewhat lower than, MOOV's 382.3 $kgCO_2e/m^2$, despite the two buildings using a similar structural typology. Part of this difference is a boundary effect rather than a material or design difference: the Brooklands figure includes the concrete foundation system (ground beams, slab, piles and reinforcement), which the study attributes 12.14% of total A1–A3 emissions to. MOOV's cradle-to-gate assessment, by contrast, is derived from the factory bill of quantities for the manufactured module and does not include site-installed footings/foundations, which are typically completed separately on-site. Were an equivalent foundation allowance added to MOOV's total, the gap between its per-m^2 intensity and the Brooklands would likely widen further.

Overall, MOOV performs well against the GBCA and Slattery benchmarks and within the international modular range, but exceeds the small set of matched-size Australian case studies, most plausibly a footprint effect rather than a materials or design issue. No standardised Australian benchmark yet exists for small-format modular housing specifically, so this comparison should be read as indicative.

At the material level, the two studies point to the same hotspot. In the Brooklands case, light-gauge steel alone accounts for 40.6% of A1–A3 emissions (32.05% at the whole-element/structural-frame level), closely mirroring MOOV's 45% steel contribution and reinforcing steel as the dominant lever for upfront carbon reduction in light-gauge modular systems generally. The Brooklands study's own sensitivity analysis found that a 15% reduction in steel mass through profile optimisation reduced A1–A3 emissions by only around 6%, a smaller relative gain than the recycled-content and route-switching (BF-BOF vs EAF) levers explored in Section 6.2–6.3 of this report, suggesting that for MOOV, sourcing and process-route decisions may offer more headroom than mass optimisation alone.

Figure 6.2 *Baseline Cradle-to-Gate (A1–A3) Embodied Carbon Profile of the MOOV Modular Dwelling*



6.1.4 Material-Level Carbon Hotspots

Analysis of material contributions identifies a relatively small number of carbon hotspots that dominate the dwelling's upfront emissions profile. As illustrated in **Figure 6.2**, structural steel accounts for approximately 45% of total A1–A3 emissions, making it by far the most significant contributor to the carbon footprint of the dwelling. Aluminium and particleboard contribute a further 12% and 9%, respectively, while manufacturing activities at MOOV's Gosford facility contribute approximately 9% of total emissions. Plasterboard, composite decking and glass-wool insulation collectively account for less than 10% of the total embodied-carbon inventory.

The concentration of embodied carbon within a relatively small number of material streams has important implications for future procurement strategies. While many materials contribute only marginally to the dwelling's carbon footprint, interventions targeting steel, aluminium and engineered wood products have the potential to deliver disproportionately large emissions reductions.

6.2 Increasing Recycled Content and Impact on Embodied Carbon

Circular-economy strategies such as increasing recycled content are often assumed to reduce embodied carbon by avoiding virgin-material extraction and processing. However, the relationship between recycled content and carbon emissions is neither linear nor uniform across different materials. To investigate this relationship, scenario modelling was undertaken for six priority materials (steel, aluminium, particleboard, plasterboard, glass-wool insulation and composite decking), which together account for approximately **70% of the dwelling's total embodied carbon** (A1–A3 emissions).

6.2.1 Scenario Modelling Approach

To evaluate the upfront carbon impact, encompassing both potential benefits and burdens of increasing recycled content in key materials, a two-stage scenario modelling approach was employed (**Table 6.1**). The baseline is determined by current market availability and procured materials for MOOV modular home. Intermediate and final recycled content are determined from supply chain engagement and research documented in “Recycled Materials Guidance Document” (Bradfield Development Authority, 2025).

It is important to note that this modelling is based on background research and Life Cycle Inventory (LCI) databases, which may not precisely reflect the specific operations of any individual manufacturer. Accordingly, the results are intended to serve as a guide for future embodied carbon estimations rather than a precise measurement of the actual carbon footprint from specific manufacturers. The scenarios should not be interpreted as procurement targets or commitments. Rather, they represent indicative trajectories intended to explore the sensitivity of embodied carbon to changes in recycled-content availability under current and emerging market conditions.

Table 6.1 *Baseline, Intermediate and Aspirational Recycled-Content Scenarios for Priority Materials*

Key materials	Baseline recycled content	Intermediate recycled content	Final recycled content
Steel	17.4%*	22-25%	28-30%
Engineered wood (particleboard)	40%	65%	90%
Insulation	66%*	80%	90%
Plasterboard	2.26-5.87% *	10-15%	20-30%
Aluminium	0%	20%	75%
Composite decking	85%	85%	99%

Note: *Where a range of recycled content is reported, the upper limit of that range has been used for the carbon footprint analysis below.*

**For Steel, Insulation and Plasterboard, the average recycled content declared in EPDs was used as the baseline, rather than the supplier-declared project figure. As a result, the target values used in this carbon analysis do not align precisely with the recommended targets set out in Chapter 5. For Steel specifically, the final target represents the ceiling value achievable under BF-BOF technology, not the higher value achievable through a transition to EAF production.*

6.2.1 Scenario Modelling Results

The baseline cradle-to-gate (A1-A3) embodied carbon assessment for the MOOV modular home, as detailed in Section 6.1, establishes an upfront carbon emission of 29,439 $kgCO_2e$ per unit (**382.3 $kgCO_2e/m^2$**). The scenario modelling evaluates the impact of transitioning from baseline recycled content levels to intermediate and final targets for the six identified key materials: Steel, Particleboard, Insulation, Plasterboard, Aluminium and Composite decking.

Figure 6.3 compares the whole-of-dwelling embodied-carbon outcomes under each scenario. The scenario modelling suggests that increasing recycled content across the six priority materials could reduce the dwelling's upfront embodied carbon by up to **10.1%**, with the intermediate scenario delivering an estimated reduction of approximately **3.5%**. This reinforces material selection, rather than construction method alone, as the more significant lever for reducing MOOV's upfront carbon footprint relative to the small-footprint Australian case studies it otherwise exceeds.

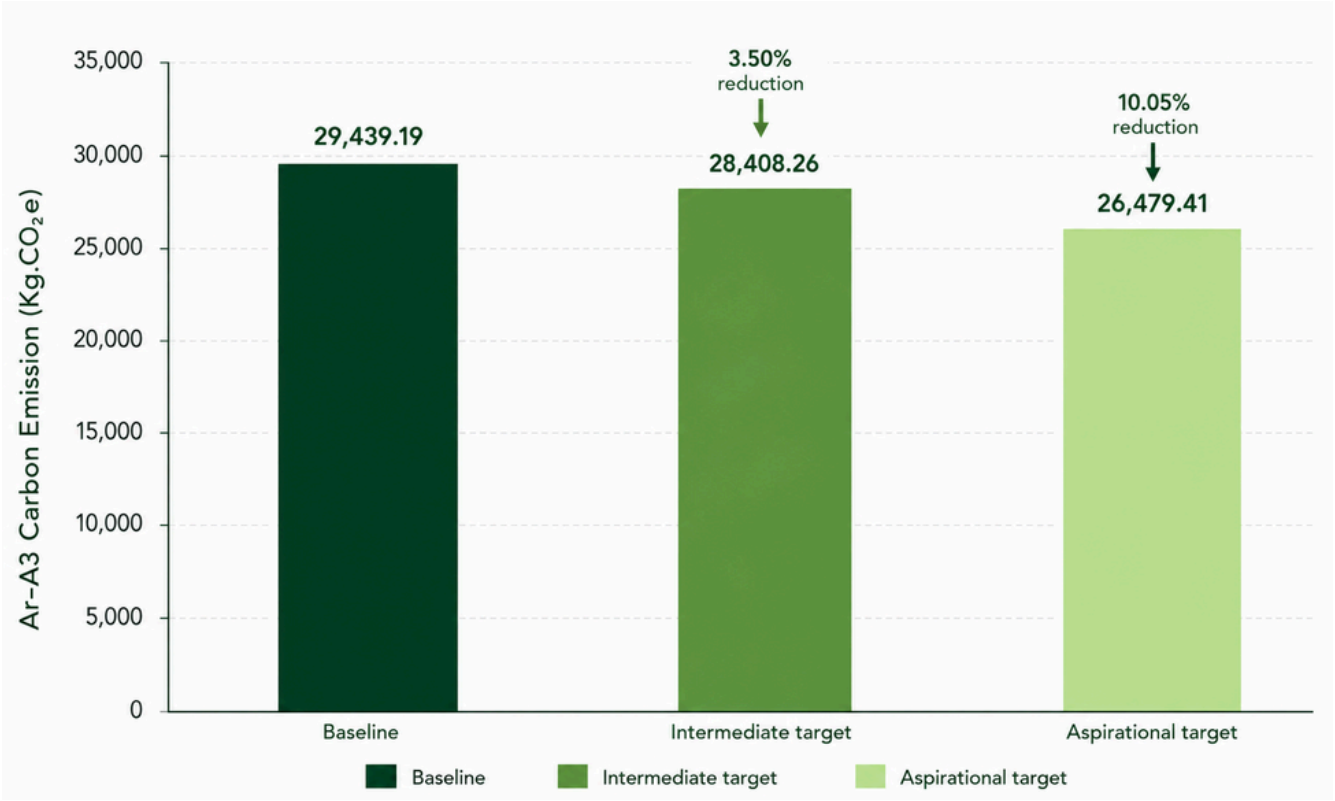


Figure 6.3 *Whole-Dwelling Embodied Carbon under Alternative Recycled-Content Scenarios*

Figure 6.4 provides a material-by-material breakdown of carbon intensity and recycled-content assumptions. The dashed line indicates the recycled content % for each material and scenario, while the columns show the resultant GWP of each material in the MOOV modular home project.

KEY OBSERVATIONS FROM THE RESULTS INCLUDE:

- Increasing the recycled content of the six key materials, up to 10.05% reduction in carbon footprint of the modular home is possible. In the intermediate recycled content, 3.5% reduction in carbon footprint is estimated.

- ***Steel***
  It is understood that up to 30% recycled content is possible using the BF-BOF technology. It is estimated that by increasing the recycled content from 17.4% (Baseline) to 30%, the carbon footprint of this material stream reduces by 5%. As previously mentioned, higher recycled content is technologically possible with other steelmaking processes such as Direct Reduction Iron (DRI) process or Electric Arc Furnace (EAF) processes, but those require longer-term structural changes to the industry to realise.

Aluminium

It is widely recognised that aluminium smelting process is energy intensive and contributes to the high carbon footprint of aluminium (20-25kgCO2e/kg for virgin aluminium). By recycling aluminium and increasing the use of recycled aluminium or aluminium scrap will reduce carbon footprint drastically. In this study, it is estimated that by increasing recycled content of aluminium from 0% to 30% will reduce the carbon footprint of this material stream by 17%. Further increase of recycled content to 75% will reduce the carbon footprint by 63% when compared to virgin aluminium.

Particleboard

The material is typically made of wood particles from the by-products and waste of logging and wood production process, rather than exclusively from whole, primary timber. Furthermore, the use of adhesives in particleboard contributes significantly to the carbon footprint of particleboard. From the assessment, it is shown that by increasing the recycled content of particleboard, the impact on carbon footprint is negligible. Having said that, by recycling / upcycling wood products such as particleboard helps reduce land use impact and reduces waste to landfill / incineration, which ultimately supports a circular economy.

Plasterboard

Plasterboard is theoretically 100% recyclable because gypsum can be dehydrated and rehydrated indefinitely. However, practical challenges, mainly contamination from other materials such as paper liners, paints and adhesives have limited the amount of post-consumer recycled gypsum that can be used. Based on the supply chain engagement and research done on the project, up to 30% recycled content is possible. By increasing the recycled content from the baseline 5.9% to 30%, a 4.5% reduction in carbon footprint of this material stream is possible.

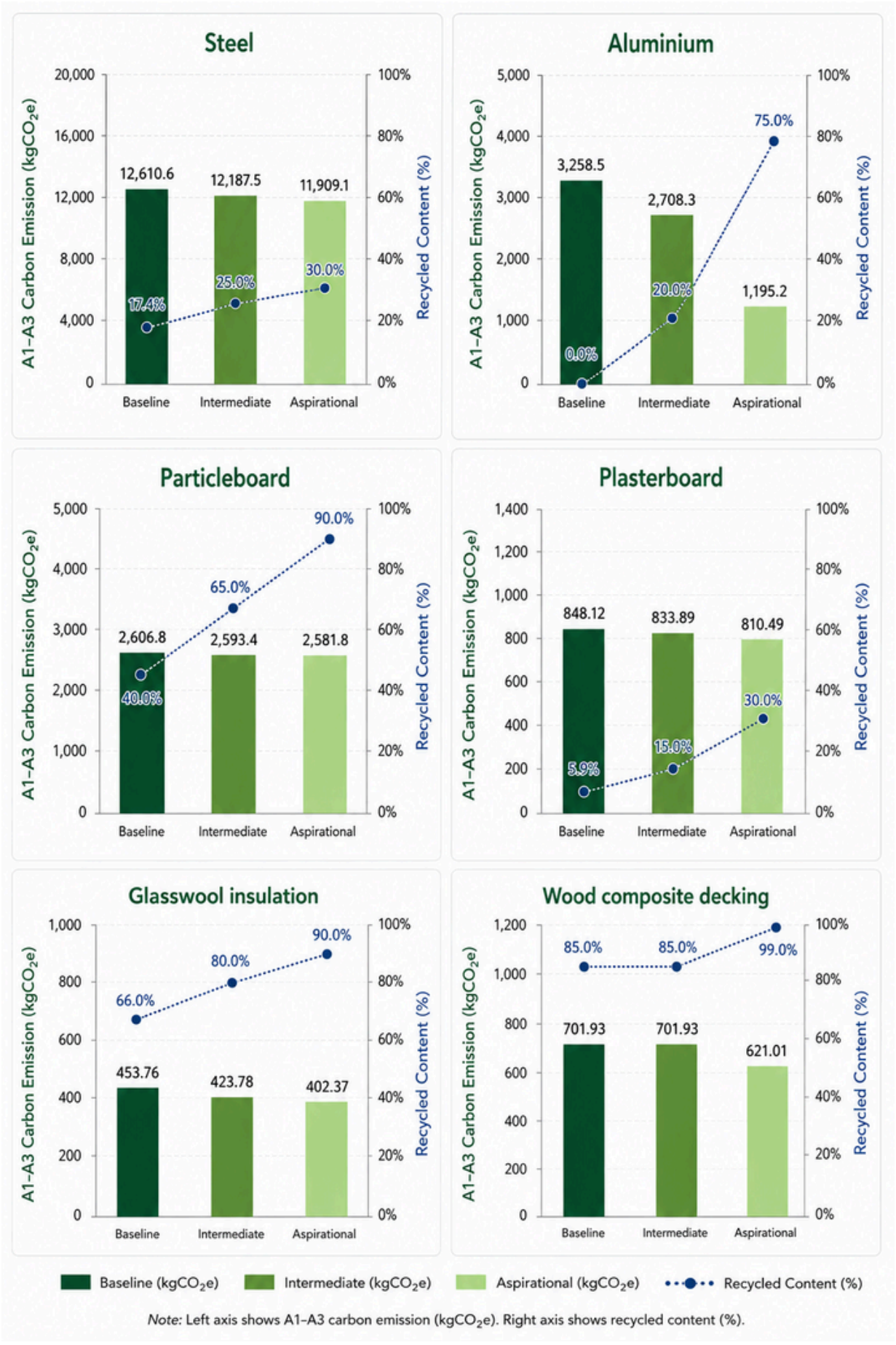
Glasswool insulation

Post-consumer or post-industrial recycled glass are typically used in glass wool insulation manufacturing. Using recycled glass diverts waste from landfill and reduces energy use (melting recycled glass cullet requires significantly less energy than melting raw materials (silica sand) that make glass. By increasing recycled content from the baseline 66% to 80%, a carbon footprint reduction of 7.5% of this material stream can be achieved. Further increasing recycled content to 90% results in additional 4% reduction in carbon footprint (or 11.5% reduction compared to baseline).

Wood composite decking

Outdoor decking made of wood plastic composite primarily comprise of recycled wood powder/fines (from industrial processes such as wood sawing/planing) and plastic resins. Based on the information in the supplier questionnaires, the current baseline recycled content of 85% could be increased to 99% in the future. It is estimated that there would be a carbon emission reduction of 11.5% for this material stream with that increase.

Figure 6.4 *Sensitivity of Material-Level Embodied Carbon to Increasing Recycled Content*



Note: Left axis shows A1–A3 carbon emission ($kgCO_2e$). Right axis shows recycled content (%).

6.3 Recycled Content and Embodied Carbon in Structural Steel: BF-BOF vs. EAF

6.3.1 Embodied Carbon (A1-A3)

Recycled content and embodied carbon are correlated but not identical metrics. For example, the carbon benefit of EAF steel comes from eliminating the energy and emissions-intensive ironmaking (coke production and blast furnace reduction) stage, not solely from recycling. Indicative A1-A3 (cradle-to-gate) global warming potential figures commonly cited in industry EPDs and WorldSteel/ResponsibleSteel benchmarking are set out in **Table 6.2**.

Table 6.2 *Indicative Comparison of Recycled Content and Embodied Carbon across BF–BOF and EAF Steelmaking Routes*

Key materials	Baseline recycled content	Intermediate recycled content
Steel	17.4%*	22-25%
Engineered wood (particleboard)	40%	65%
**These are indicative industry benchmarks without considering any coating and fabrication processes; project-specific figures should be substituted from verified EPDs for the actual mills under consideration.*		

6.3.2 The Australian Context

Australia's domestic steel production is overwhelmingly BF-BOF-based, centred on BlueScope's integrated BF-BOF operations at Port Kembla, NSW. This means:

- Locally produced structural and roofing steel (e.g., COLORBOND, ZINCALUME base metal from Port Kembla) is predominantly BF-BOF-derived, with the recycled content and carbon footprint characteristics described above.
- Genuine EAF-based flat and roofing-grade steel is not significantly produced domestically at scale. Australia does have EAF capacity (e.g., Liberty Steel's Whyalla operations, and some EAF long-product mills), but these are focused on long products (rebar, structural sections) rather than roofing-grade coated sheet.
- To source EAF-based sheet steel with a documented, low A1–A3 carbon footprint and high recycled content, one would likely need to import product from overseas EAF mini-mills (e.g., US-based Nucor or Steel Dynamics, or EAF-based European producers), introducing:
- Additional transport-related emissions, which partially offset the A1–A3 carbon saving and must be assessed on a full cradle-to-site basis, not A1–A3 alone.
- Longer lead times and potential cost premiums for imported product versus domestic BF-BOF supply.
- Practical sourcing constraints - availability of roofing-specific coated coil (as opposed to hot/cold-rolled coil) from EAF mills needs to be confirmed per product form, since coating/finishing may still occur at a separate facility.
- Alternatively, BlueScope has published decarbonisation commitments and is investigating EAF/DRI transition pathways for future Australian production, but current product is BF-BOF-based; the project timeline should be checked against BlueScope's roadmap if this is a consideration.

6.3.3 Indicative upfront carbon reduction by using EAF steel

Figure 6.5 shows the potential carbon reduction of using EAF steel in the context of MOOV modular home. As shown earlier, steel contributes 45% to the overall carbon emission of the modular home. By using EAF steel, there is a potential 20.5% reduction compared to the baseline carbon footprint. It should be noted that estimation is not specific to any EAF steel mill, rather it's based on publicly available data on EAF steel carbon footprint globally.

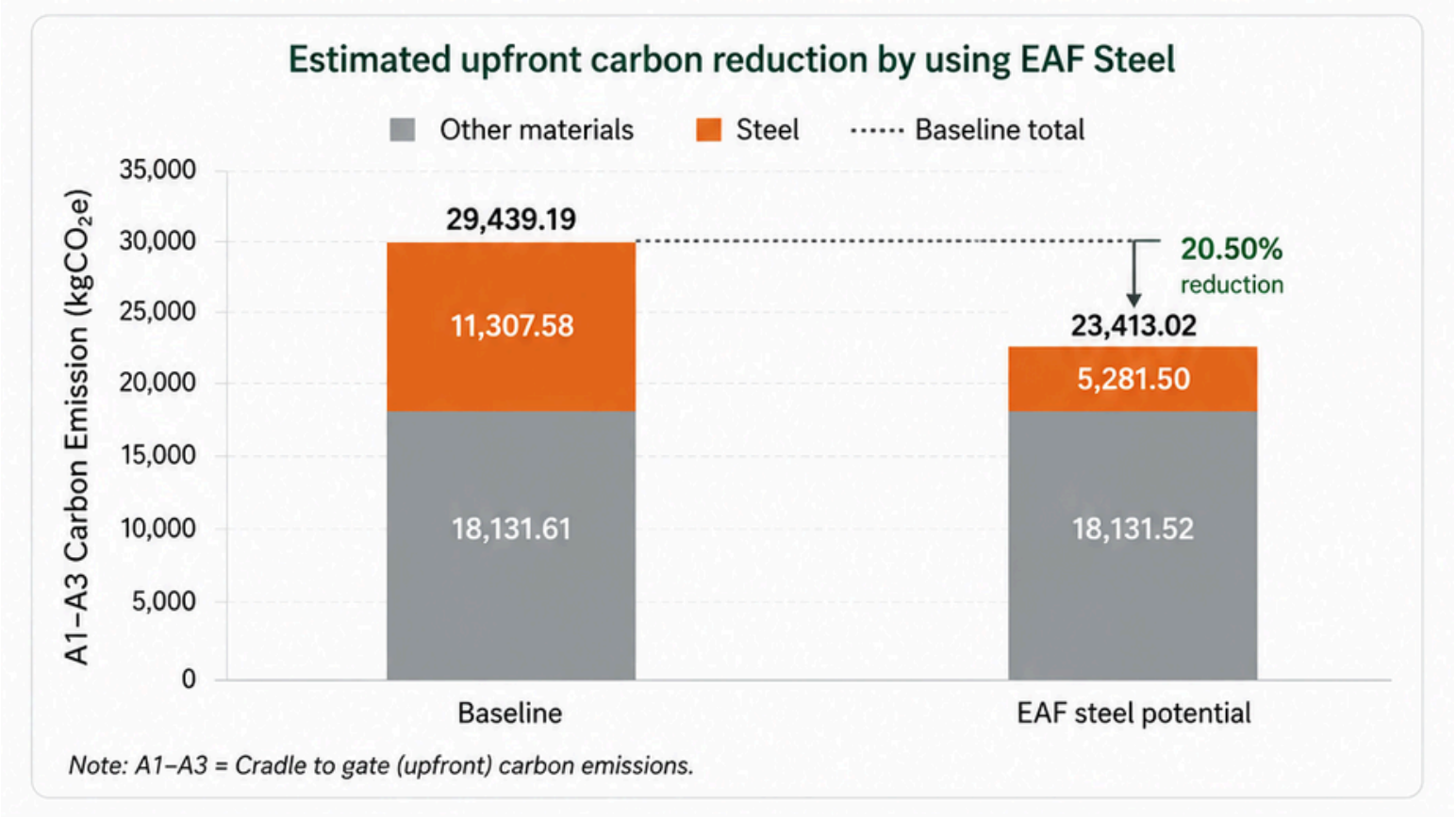


Figure 6.5 *Estimated Upfront Carbon Reduction Associated with EAF Steel Adoption*

6.3.4 Scrap Availability and the Limits of Recycled-Content-Led Decarbonisation

Increasing scrap use in steel does not automatically translate into a net reduction in embodied carbon, and BlueScope's response usefully qualifies this relationship for structural steel supplied to MOOV. For BlueScope's integrated BF-BOF steelmaking at Port Kembla, scrap use is technically constrained by process heat balance, steel chemistry and final product-performance requirements, meaning there are practical limits to how much additional scrap can be incorporated without changes to steelmaking technology or process configuration.

More fundamentally, steel is one of the most recycled materials in the world, but global scrap supply is insufficient to meet growing steel demand — scrap is therefore a resource-constrained material, where supply volume is limited, is already below current demand, and does not readily expand in response to further demand growth (IEA, 2021; worldsteel, 2021). Because of this constraint, directing a higher share of available scrap toward one project reduces the scrap available elsewhere, meaning specifying higher-recycled-content steel for MOOV would not reduce global emissions overall but would instead shift the accounting benefit from one buyer to another, an effect sometimes referred to as “emissions shuffling.” This is consistent with guidance from the Institution of Structural Engineers UK, which notes that high-scrap steel (such as that produced by many electric arc furnaces) is often appropriate for construction use, but should not be specified on the basis that doing so reduces global greenhouse gas emissions (Institution of Structural Engineers UK, 2025).

This is the same constraint underlying the 5% project-level carbon reduction modelled in Section 6.2 for increasing steel's recycled content from 17.4% to 30%: that figure represents a reduction in this project's accounted emissions rather than a verified reduction in global steel-sector emissions, since it relies on directing a larger share of a constrained global scrap pool toward this project specifically.

BlueScope is nonetheless pursuing process improvements that may support incremental increases in scrap use over time, including a torpedo (hot-metal transport vessel) lid trial intended to conserve heat and allow greater scrap incorporation, an example of technology-level rather than sourcing-level decarbonisation. Recommendations for managing embodied carbon in steel specification consistent with these constraints are set out in BlueScope's published guidance on embodied carbon and steel products (BlueScope, n.d.).

6.3.5 Implication for Homes NSW

If recycled content and A1–A3 carbon reduction are primary drivers, EAF-sourced steel offers a substantially stronger outcome on both metrics, but in the Australian context this will most likely mean imported product, and the full-lifecycle (including transport) carbon case should be modelled before concluding it is the lower-carbon option overall. If domestic sourcing, shorter lead times, or cost certainty are prioritised, BF-BOF steel from Port Kembla remains the practical default, with recycled content and carbon reduction addressed instead through specification efficiency, minimising waste, and end-of-life recyclability of the steel used. Given the scrap-availability constraints set out above, Homes NSW should also treat project-level recycled-content increases in BF-BOF steel as a specification and traceability improvement rather than a guaranteed net reduction in global emissions, and should look to process-level and route-level interventions (such as BlueScope's own decarbonisation pathway, or EAF sourcing where feasible) for verifiable global emissions reduction.

7 Recommendations and Next Steps

This chapter draws together the findings of all five activities carried out for this study: the literature review of Australian and international circular-economy practice, the supply chain mapping and data collection exercise, the material and supply chain opportunity analysis, the recycled-content baseline and benchmark assessment, and the embodied carbon assessment. The key findings across these activities have been consolidated into recommendations, grouped under six headings: circular design and construction; procurement and market leverage; verification and traceability; material-specific targets; embodied carbon; and policy, standards and industry engagement.

7.1 Circular Design and Construction

The literature review considered more than 100 publications, policies, standards and case studies from Australia and ten international jurisdictions, including New Zealand, the United Kingdom, Singapore, Japan and China. A consistent theme across this material is that circularity outcomes — including maximising recycled content and minimising both embodied and lifecycle carbon — are largely set at the design stage. Once a modular dwelling has been fabricated, later substitution of materials or components can only do so much; the decisions that matter most are made before manufacturing begins.

Recommendation 1: Design for disassembly from concept stage

Case studies reviewed for this project show that design for disassembly works best when it is part of the original design brief rather than something added once a design is largely finalised. Homes NSW should require standardised mechanical connections, accessible service routes and reusable structural systems as a default expectation for future modular projects, irrespective of the modular manufacturer. Doing so would extend asset longevity and help secure future supplies of recycled material through material recovery at end of life.

Recommendation 2: Standardise module dimensions and component interfaces across suppliers

Standardisation was repeatedly identified in the literature as an enabler of circularity, scale and cost efficiency in the modular housing sector internationally. Homes NSW should work with its supply base to agree common module dimensions, connection details and manufacturing processes. This would make replacement, refurbishment, relocation and reuse of components more straightforward, and over time could support a genuine market for second-life components maximising the government's value for money and minimising future costs.

Recommendation 3: Design for adaptability and multiple future uses

Future dwellings should be capable of accommodating changing occupant needs over time, for example through reconfigurable internal layouts or adaptable service cores. This reduces the likelihood of premature demolition and helps preserve the value of embedded recycled content over a longer asset life.

7.2 Procurement and Market Leverage

The supply chain mapping and opportunity analysis both point to the same conclusion: Homes NSW's leverage over recycled content is not evenly spread across the supply chain, it is concentrated in a handful of decisions made early in procurement.

Recommendation 4: Build evidence and verification requirements into procurement up front

A core difficulty encountered in this project was retrofitting a verification exercise onto claims and documentation that suppliers had not been asked to prepare with project-level traceability in mind. Recycled-content evidence requirements, including methodology disclosure, product specificity and chain-of-custody documentation, should be written into the RFT or supply contract for future modular projects as a condition of participation, not requested as an afterthought once materials have already been ordered.

Recommendation 5: Extend this assessment across the remaining panel, using MOOV as the benchmark

Homes NSW should commission the same recycled-content and carbon verification exercise for its other modular suppliers, assessing each supplier's own materials and evidence in full, while drawing on the methodology, benchmarks, and lessons learned from this project rather than starting from a blank page. This gives Homes NSW a like-for-like baseline across the full panel rather than a single data point.

Having comparable data for all modular manufacturers also allows one of two positive outcomes — or possibly a bit of both. If the manufacturers all share similar sources of materials, it provides Homes NSW with even greater leverage to drive improvements in use of recycled materials with those concentrated suppliers.

If they use different suppliers with varying levels of performance, it provides case data from which best-in-class materials can be cross-recommended to other manufacturers. Both would be valuable for minimising environmental impact. This would also allow Homes NSW to propagate best-practice learnings across its manufacturer panel, so that stronger performers and weaker performers alike can learn from a shared, comparable evidence base.

Periodically rerunning the analysis at defined intervals across the rollout of the 8,000-dwelling program can also turn this project from a one-off verification exercise into a longitudinal performance record demonstrating how the program is driving improvements over time.
GECA would be happy to continue supporting this program of work. Commissioning the same body to apply a consistent methodology across all four suppliers would maximise comparability of results.

Recommendation 6: Prioritise a small number of strategic, high-volume suppliers

The supply chain mapping identified more than 20 major material categories, but a relatively small number of manufacturers account for most of the dwelling's material mass, each supplying multiple product categories. Focused engagement with this smaller group is likely to achieve materially greater recycled-content outcomes, at a fraction of the effort, than pursuing individual product substitutions across the full breadth of the supply chain.

Recommendation 7: Specify recycled content and carbon requirements at tender stage

Suppliers engaged for this study ranked government procurement requirements and customer demand as the two strongest drivers of recycled-content uptake, ahead of factors such as recycling infrastructure investment. As the client for this and future modular programs, Homes NSW sits directly inside the lever suppliers themselves say matters most. Recycled-content and carbon requirements should be written into tenders as performance-based outcomes, not raised as an attribute after contracts are signed.

Figure 7.1 summarises the key drivers identified by suppliers for increasing recycled content uptake.

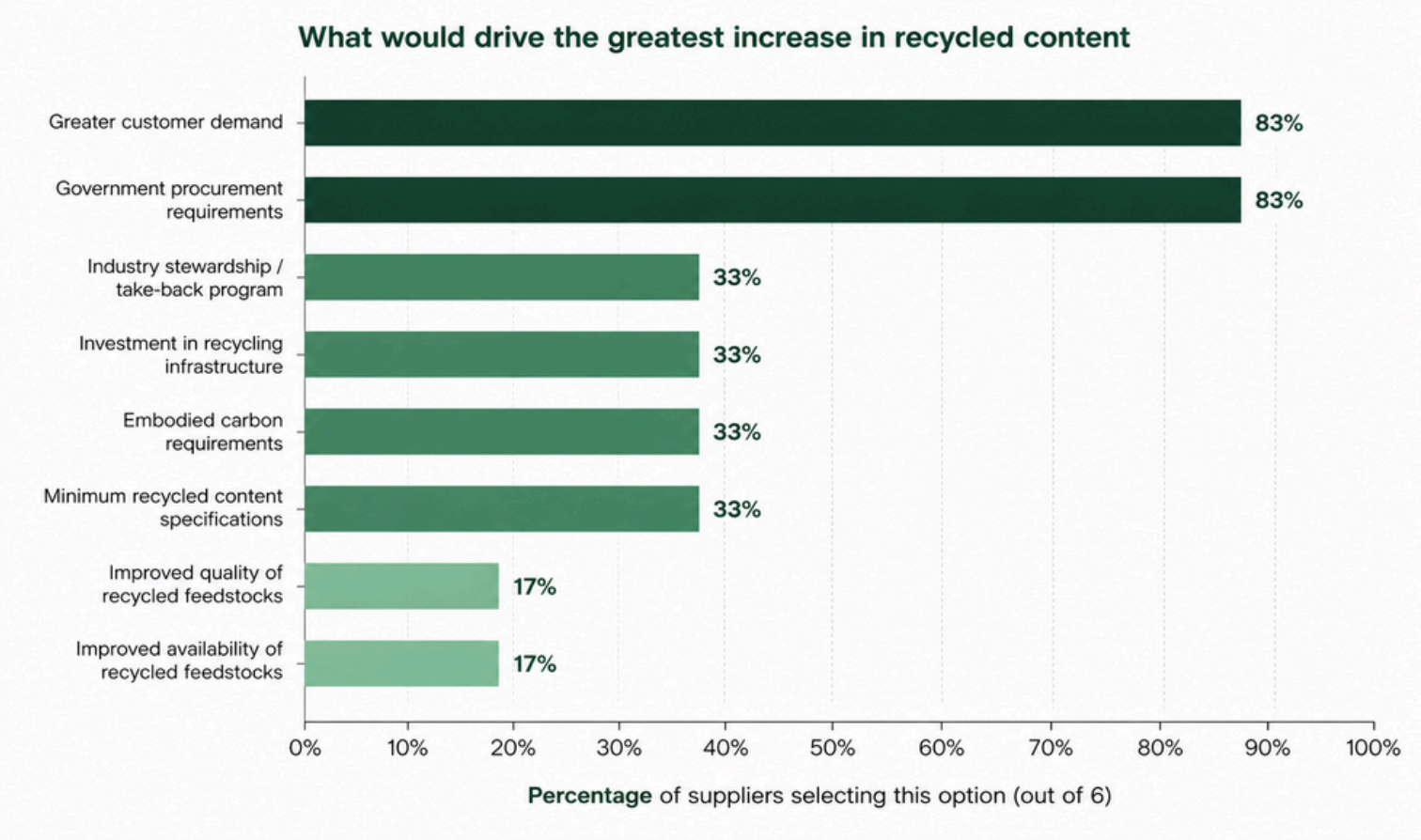


Figure 7.1 *What would drive the greatest increase in recycled content, by number of suppliers selecting each option (out of 6)*

7.3 Verification and Traceability

Recommendation 8: Track two dwelling-level KPIs: recycled content and verification confidence

Homes NSW should consider tracking two different figures for each dwelling: the recycled-content percentage, and a weighted confidence score indicating how much of that figure is independently verified with credible evidence (rather than self-declared). This project's usable output is a 20.1 % dwelling-level figure alongside its confidence score. Publishing both figures together as separate metrics stops an unverified claims or those with weak or missing data from being read with the same authority as independently-assessed, comprehensive ones. It also provides Homes NSW with a clear measurement of progress as suppliers make improvements in both product and process. The confidence score should rise even in years where the content percentage itself does not change if manufacturers are continuing to improve their data capture and tracking.

Recommendation 9: Require third-party verified evidence for carbon and recycled content, phased by material maturity

Homes NSW should require third-party verified carbon figures, whether an EPD, a product carbon footprint, or another ISO 14067-aligned pathway, alongside recycled-content claims verified against the National Framework for Recycled Content Traceability, for all priority materials. The independent evaluation provides consistent and comparable results enabling confidence in procurement processes and impact reporting. For materials where embodied carbon infrastructure is already mature, such as steel and insulation, this can be required immediately, with the remaining gaps addressed through better linkages between site averages and specific product data. For materials where verification infrastructure is still developing, such as engineered wood, a defined transition timeline tied to authentication milestones is more realistic than an immediate compliance requirement.

Recommendation 10: Disclose whether a claim is product-specific or a manufacturing average

This project found that a transparent, product-specific figure can sit below a higher but non-specific figure and still represent the stronger piece of evidence. A single, low, product-specific plasterboard claim, for instance, is more useful to an evaluator than a higher, site-averaged steel claim that cannot be linked to what was actually delivered. Similar to Recommendation 8 (applied to dwellings), Homes NSW should disclose this distinction at the material level as an additional data field until alignment with the National Framework becomes standard practice across the market, at which point a separate field should no longer be necessary.

Recommendations 8 to 10 describe a staged path rather than a single compliance step. **Figure 7.2** sets this out as a four-tier maturity pathway, moving from standardised supplier declaration through to a fully digital, verified procurement system, with an indicative implementation timeframe for each stage.

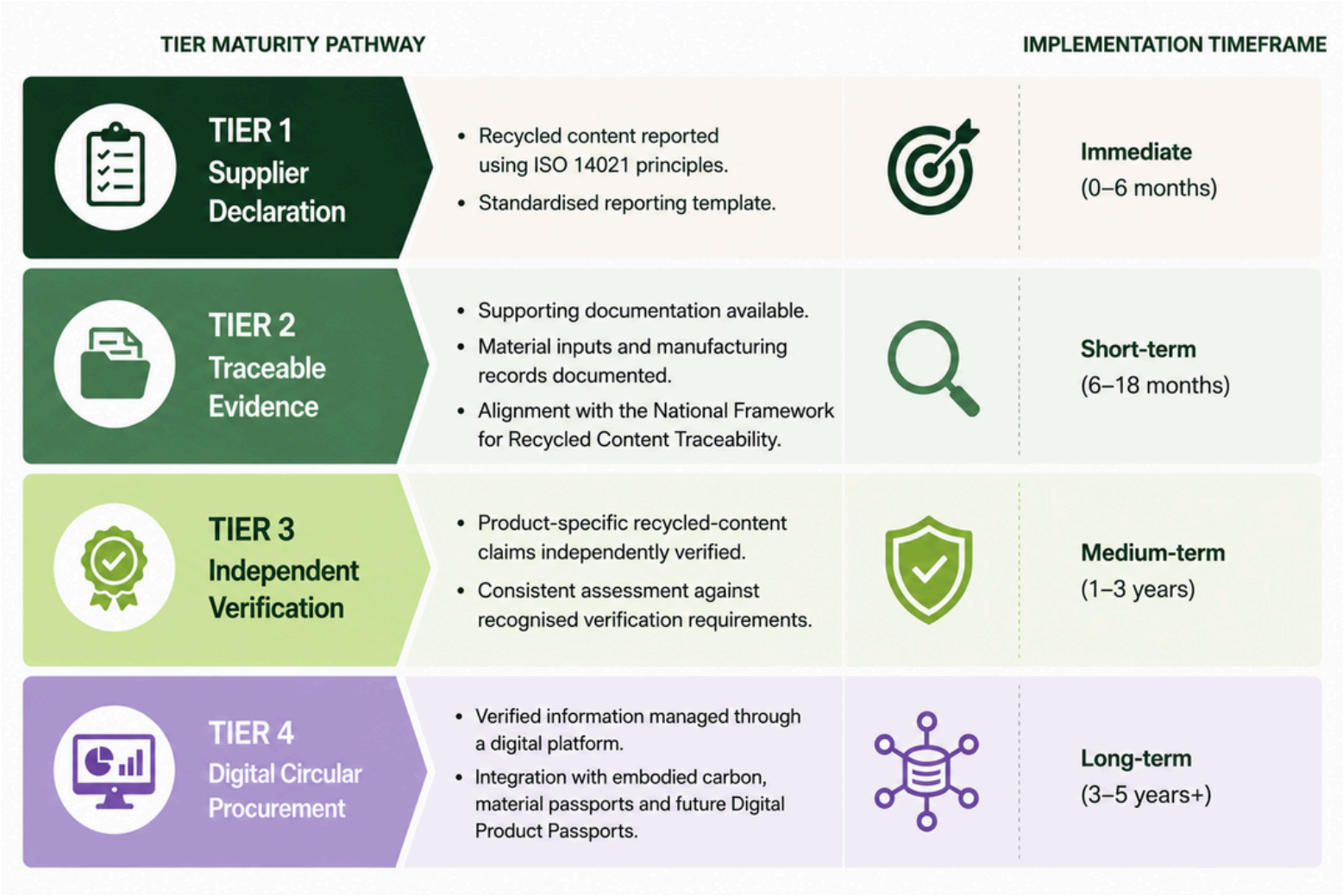


Figure 7.2 *Proposed Circular Procurement Maturity Pathway*

7.4 Material-Specific Targets

Recommendation 11: Set recycled-content ceilings by material rather than a single blanket target

Industry evidence gathered for this project shows that steel's recycled content is constrained by process chemistry and heat balance as much as by sourcing choices, and that global scrap availability places a further ceiling on what is achievable. Aspirational recycled-content targets should therefore be calibrated per material against realistic, internationally benchmarked ceilings, as this report has done for structural steel, plasterboard, engineered wood, composite decking, aluminium and insulation, rather than applying one target uniformly across every material category. **Table 7.1** sets out the recommended target range and immediate procurement priorities for each of the six priority material streams assessed in this study.

Table 7.1 *Summary of Recycled-Content Benchmark Findings and Procurement Priorities by Material Stream*

Material	Current	Global Best Practice	Gap	Procurement Priority
Structural Steel	24% *(17%)*	60–90%	▲ High	• Transition toward EAF steel • Specify minimum technology-aligned recycled content • Require product-specific EPDs/Claims
Plasterboard	4–7%	20–30%	▲ Very High	• Require separate liner vs. gypsum-core disclosure • prioritise suppliers with verified take-back schemes • Stage targets as supply matures
Engineered Wood (Particleboard)	40%	70–90%	▲ Medium	• Increase recycled fibre requirements while maintaining product performance • Require product-specific verified claims • Embed targets in tenders
Composite Decking	85%	95–99%	▼ Low	• Maintain current performance • Adopt market-leading and verified products above 90% where available
Aluminium	0%	30–75%	▲ Very High	• Introduce recycled billet specifications in procurement and ASI Chain of Custody • Target 20–30% near-term minimum
Insulation	82%	85–90%	▼ Low	• Maintain high recycled-content products • Favour verified EPDs/Claims

7.5 Embodied Carbon

Recommendation 12: Prioritise aluminium, and steel production route, as the strongest carbon levers

Aluminium is the clearest case in this study of recycled content and carbon reduction moving strongly together. Increasing recycled content from 0 to 30 % is estimated to cut aluminium's carbon footprint by 17 %, and a further increase to 75 % content by 63 % emissions cut, reflecting how energy-intensive primary aluminium smelting is compared with remelting scrap. Steel presents a more layered picture.

Within conventional blast furnace and basic oxygen furnace production, recycled content is limited to roughly 15 to 30 % by process chemistry rather than scrap availability alone and increasing it toward that ceiling delivers a comparatively modest reduction of around 5 %. Electric arc furnace steel, which typically runs at 80 to 100 % recycled content, produces a materially larger reduction, in the order of 20.5 % against this dwelling's baseline, since the carbon benefit here comes mainly from avoiding the ironmaking stage rather than recycled content alone.

Australia's domestic steel production remains overwhelmingly based on the blast furnace and basic oxygen furnace route. Genuine electric arc furnace capacity for roofing and cladding-grade sheet steel is not produced domestically at meaningful scale; existing domestic electric arc furnace capacity is oriented toward long products such as reinforcing bar and structural sections rather than coated sheet. Sourcing electric arc furnace sheet steel with a documented, low-carbon footprint would most likely mean importing from overseas mills, which introduces additional transport emissions that partly offset the carbon saving, longer lead times, potential cost premiums relative to domestic supply, as well as the political dimension of failing to preference local production.

If recycled content and upfront carbon reduction are the primary drivers for a given project, electric arc furnace steel offers the stronger outcome on both counts, but the full transport-inclusive carbon case should be modelled before it is treated as the lower-carbon default. Where domestic sourcing, shorter lead times or cost certainty matter more, domestically produced steel remains the practical choice, with recycled content and carbon addressed instead through specification efficiency, waste minimisation and end-of-life recyclability. Even with domestic BOF production, there is still room to work with suppliers to both increase the amount of recycled content in the steel and improve tracking of data so accurate product-level measurements can be provided.

Recommendation 13: Expect recycled content and carbon reduction to move together for some materials and not others

The scenario modelling shows this relationship varies considerably by material. For particleboard, increasing recycled content has a negligible effect on carbon footprint, since adhesive content rather than the wood fibre itself is the dominant emissions source; the case for uplift here rests on waste diversion and circularity rather than carbon. Plasterboard sits in between: increasing recycled content from a baseline of around 5.9 % to 30 % is estimated to reduce carbon by around 4.5 %, with practical uplift constrained more by contamination in recovered gypsum than by any technical limit. Glass wool insulation responds more strongly, with an increase from 66 to 80 % recycled content estimated to reduce carbon by 7.5 %, and a further increase to 90 % adding another 4 %, for an 11.5 % reduction overall relative to baseline. Wood composite decking, similarly, is estimated to achieve an 11.5 % reduction if recycled content rises from 85 to 99 %. Homes NSW should use this material-by-material variation to prioritise procurement effort where it will most impact differing policy goals, rather than assuming that recycled-content uplift delivers a comparable carbon benefit everywhere.

7.6 Policy, Standards and Industry Engagement

The literature review found that Australia has established many of the building blocks needed to support circular modular construction: a growing range of recycled-content products, an increasing number of products with verified embodied carbon data, and emerging procurement policy. Compared with international leaders, however, Australia continues to lag in nationally consistent verification, digital material traceability, material passport systems and mandatory embodied carbon reporting. The rankings of industry constraints collected through supplier engagement point to where policy attention should be directed.

Recommendation 14: Calibrate supplier engagement to the specific constraint each material faces, and engage jointly with other agencies and jurisdictions to increase influence

When examining barriers to increasing recycled content in products, cost was ranked the dominant constraint for composite decking, engineered wood and plasterboard. Feedstock quality was the leading constraint for structural steel. Product performance and quality consistency dominated for insulation--where cost was ranked least significant--and supply chain limitations were the leading constraint for aluminium. Homes NSW's engagement strategy with key suppliers should reflect these differences rather than applying a single, generic recycled-content requirement across every material.

Figure 7.3 illustrates the key barriers identified by suppliers to increasing recycled content uptake.

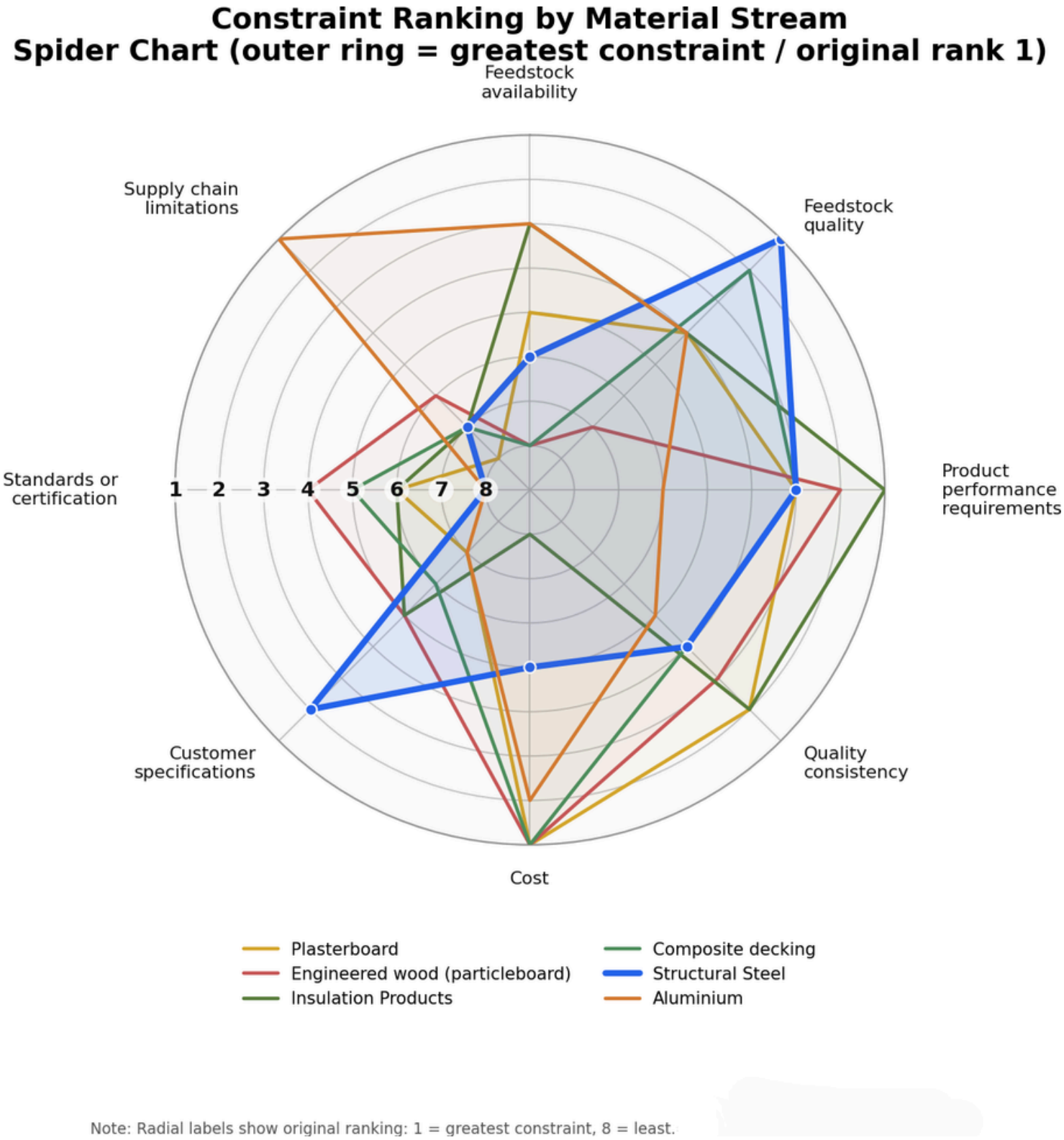


Figure 7.3 *Constraint ranking by material stream (1 = greatest constraint, 8 = least; Structural Steel not provided)*

Some of these challenges are system-wide barriers where it is unlikely that any single project is big enough to drive the needed changes. Homes NSW should work with as many other agencies as possible, whether in NSW or in other jurisdictions, to jointly promote the needed changes and provide aligned procurement requirements. Big changes in industry often require larger commercial opportunities supported by clearer and consistent minimum expectations in procurement requirements.

Recommendation 15: Support the national policy and standards work needed to close Australia's remaining gaps

While Australia's policy landscape has a number of gaps still relative to other jurisdictions, there are actions that can be taken to narrow those gaps right now. Homes NSW should consider referencing the Green Building Council of Australia's Responsible Products Framework as a guide for good practice in material selection. It should advocate for recognition of recycled content and embodied carbon within future updates to the National Construction Code, and treat its own tiered reporting framework, set out in Recommendations 8 to 10, as a practical model of what traceability in practice can look like pending changes to national policy. This reflects a consistent finding of this study: Australia's principal constraint on recycled-content and traceability infrastructure is one of policy and market maturity rather than technical capability.

Recommendation 16: Prioritise local provenance alongside recycled content as a supplier evaluation criterion

This project's scope focused on verifying recycled content and carbon performance but could not assess the geographic origin of materials or the local recycling infrastructure behind them. As Homes NSW extends this work across its remaining supplier panel, there is an opportunity to drive local provenance, sourcing from local manufacturers and working with local recyclers and reprocessors, into future evaluation criteria alongside recycled content and carbon verification. This would support the maturity of local recycling and remanufacturing infrastructure directly, rather than solely rewarding recycled content sourced through offshore or unverified supply chains, and strengthens the case for a genuinely circular local materials economy underpinning the 8,000-dwelling program, not just a lower-carbon one. Using verified recycled content with appropriate provenance data would also allow Homes NSW and other agencies to confidently track and report how much waste these projects are diverting from landfill into new materials, supporting NSW waste policy outcomes.

Appendix A: Reference Documents and Regulatory Mapping

The following documents were used as references for the Literature Review Activity.

AUSTRALIA

2026	NABERS	Embodied Carbon – The Rules v2.1	Technical rules document setting out NABERS' embodied carbon assessment methodology, including system boundary definitions, calculation requirements and database of emission factors for building materials.
2025	Bradfield Development Authority	Recycled Materials Guidance Document	Provides guidance on the use of recycled materials and products in the built environment, including optimal levels of recycled content for different building materials, products and components.
2025	DCCEEW	Recycled Content Traceability Framework	National guideline to track, verify and report recycled content across supply chains.
2024	DCCEEW	Circular Economy Framework	National policy driving circular economy and increased recycled material use.
2024	ABCB	Modular Construction Handbook	Guidance on NCC compliance for prefabricated and modular construction.
2022–2025	ABCB / Australian Government	National Construction Code	Mandatory performance requirements for all buildings including modular systems.
2026	Curtin University/The Legacy Living Lab (L3)	The Legacy Living Lab (L3)	The Legacy Living Lab homepage. See also project video on YouTube.
2026 (a)	Curtin University/The Legacy Living Lab (L3)	The future is modular	Article explaining the background and objectives of The Legacy Living Lab.
2025	Productivity Commission	Australia's Circular Economy – Unlocking the opportunities	A report into the Productivity Commission's Inquiry into realising circular economy opportunities in Australia, including recommendations for the built environment.

2025	Senaratne, S. et al (*Buildings* 2025, *15*(9), 1515; https://doi.org/10.3390/buildings15091515)	*Exploring Challenges and Strategies in Circular Economy Applications in Modular Construction: The Case in Australia*	Explores the challenges and strategies for deploying circular economy thinking in modular housing in Australia.
2025	Shooshtarian, et al. (Journal of Environmental Management, 389, 126108).	*Circular economy policies and the use of recycled materials in the Australian built environment*	A review of the effectiveness of different policy instruments in supporting the uptake of products with recycled content.
2022	Recycling Near You	*Recycling Near You*	*Uncontaminated plasterboard is completely recyclable* — National construction and demolition waste generation and recovery-rate data. Used to benchmark Australia's overall C&D waste recovery performance against plasterboard-specific recycling.
2025	GBCA	Our Homes Weigh a Tonne	Technical report modelling embodied carbon for a typical Australian detached house.
2023	Illankoon, S. et al.	Embodied Carbon in Australian Residential Houses: A Preliminary Study	Case study measuring embodied carbon across a few Sydney homes.
2022	Slattery	Upfront Embodied Carbon Benchmarks — Measure to Manage: Benchmarking Embodied Carbon in Australia	National Australian benchmarking report.

NEW SOUTH WALES

2026	NSW DCCEEW	Recycled Content Reporting Guide	Mandatory reporting framework for recycled content in government procurement.
2025	NSW Government	Modular Building Reforms	Proposed streamlined approvals and regulatory clarity for modular construction.
2025	NSW Government	Recycled Materials Guide	Supports specification and uptake of recycled materials in construction.
2024	NSW Government	Net Zero Government Policy	Requires public agencies to reduce emissions and increase recycled content in procurement.

2024	NSW EPA	State of Environment – Waste	Tracks waste and recycling trends supporting circular economy policies.
2023–2024	NSW EPA	Using Recycled Materials	Practical guidance for businesses on incorporating recycled materials.
2023	NSW EPA	PEP Sustainable Construction	Circular economy policy and delivery plan for the construction sector (includes low-carbon materials and mandatory recycled content targets in infrastructure).
2023	NSW EPA	Circular Economy Delivery Plan	Supports circular economy transition and recycled material market development.
2023	NSW Government	Circular Design Guidelines	Promotes modularity, reuse and integration of recycled materials.
2021–2041	NSW Government	Waste & Sustainable Materials Strategy	20-year plan to increase resource recovery and recycled content in NSW's economy.

INTERNATIONAL

2026	European Commission	Circular Economy Act (upcoming 2026)	Upcoming EU Circular Economy Act designed to establish a single market for secondary raw materials, increase recycled content demand, and accelerate circular transition across industries, including construction.
2026	United Nations Environment Programme	Global Buildings Status Report 2026 context updates	Latest updates emphasise continued acceleration of building sector decarbonisation, with increased focus on circular materials, embodied carbon reduction, and net-zero construction pathways.
2026	European Commission	EU circular water systems initiative	New initiative (2026) supporting investment in circular water systems, promoting reuse, resource efficiency, and industrial water circularity across EU member states.
2026	European Commission	EU infrastructure and circular investment projects	Funding announced for infrastructure projects supporting circular economy principles, including resource efficiency, reuse systems, and low-carbon construction materials.
2026	OECD	OECD Circular Economy Construction Analysis	Continued OECD analysis of global construction material flows, highlighting increasing policy convergence toward circular construction and industrial symbiosis.

2026	European Environment Agency	Construction & demolition waste EU analysis	Updated EU analysis of construction and demolition waste streams, showing rising recycling rates but persistent gaps in high-value material recovery.
2026	Sustainability Atlas	Construction waste & circular buildings — what's working, what's not, and what's next	A comprehensive state-of-play assessment for Construction waste & circular buildings, evaluating current successes, persistent challenges, and the most promising near-term developments.
2025	European Commission	Packaging Waste Regulation (PPWR)	EU Packaging and Packaging Waste Regulation introduces stricter reuse, recycling, and material reduction targets across supply chains.
2024	International Organization for Standardization	ISO 59020:2024 *Circular economy — Measuring and assessing circularity performance*	ISO 59020 defines reused content as: '*A component or part that has reached the end of one use, and is used again with minimal or no physical alterations*'.
2020	International Organization for Standardization	ISO 20887:2020 - *Design for disassembly and adaptability in buildings*	International Standard to support design for disassembly and adaptability in buildings.
2016	International Organization for Standardization	ISO 14021 - *Environmental labels and declarations — Self-declared environmental claims*	ISO 14021 sets the ground rules for any self-declared environmental claims, included claims made about the percentage of recycled content in materials and products.
2024	European Commission	Ecodesign for Sustainable Products Regulation	ESPR introduces binding sustainability requirements for product design, durability, repairability, and recyclability, forming a cornerstone of EU circular economy policy.
2024	Council of the European Union	Construction Products Regulation (CPR)	Updated regulation harmonising construction product standards, introducing digital product passports and stronger circular economy requirements for building materials.
2024	United Nations Environment Programme	Global Status Report for Buildings and Construction 2024	Global assessment of emissions and resource use in buildings, identifying construction as a major driver of global CO_2 emissions and material consumption.

2018	United Nations Environment Programme	Building Circularity into Our Economies through Sustainable Procurement	Introduces the role that sustainable and circular procurement can play to accelerate the transition to a circular economy.
2023	Chen, S. et al	Reducing embodied carbon in concrete materials: A state-of-the-art review	A detailed study into reducing the embodied carbon in concrete products by utilizing low-carbon concrete materials (LCCMs).
2023	OECD	OECD Circular Economy and Construction Transition	Examines policy frameworks and material flow efficiency in construction, focusing on systemic transition to circular building systems.
2023	World Economic Forum	Future of Construction Report	Highlights industrialised construction, modular building systems, and circular economy integration as key trends shaping the future of the sector.
2021	International Energy Agency (IEA)	https://www.iea.org/reports/iron-and-steel-technology-roadmap	*Iron and Steel Technology Roadmap Report* — Global analysis of steel decarbonisation pathways and scrap availability constraints.
2020	European Commission	EU Circular Economy Action Plan	Foundational EU strategy under the European Green Deal aiming to reduce waste, increase reuse, and embed circular economy principles across product life cycles, including construction.
2020	McKinsey & Company	Modular Construction. From projects to products.	Provide an overview of the global modular construction industry, including benefits, different methods and modes of construction, industry drivers and trends.
2011	Misfits architecture	Prefab Parametric! – misfits'architecture	Provide reference Images of the BoKlok prefabricated buildings.
2025	O'Hegarty, M. et al.	Understanding the embodied carbon credentials of modern methods of construction	Systematic review of 82 international case comparisons of modular and prefabricated construction, finding embodied carbon intensities of roughly 140–860+ kgCO2e/m² depending on structural material, with no consistent embodied-carbon advantage over traditional construction.

BY COUNTRY

Japan	2022 – 2023	Ministry of Land, Infrastructure, Transport and Tourism (MLIT)	https://www.mlit.go.jp/en/	Highly industrialised housing market (Sekisui House model). Strong prefabrication culture, long-life housing standards, and national construction waste recycling under resource circulation laws.
	n.d.	Sekisui House	https://www.sekisuihouse-global.com/	Modular wood framed homes.
	2019	Passarelli, R.N (Modular and Offsite Construction (MOC) Summit Proceedings – 2019)	https://journalofindustrializedconstruction.com/index.php/mocs/article/view/89/87	Paper on: Environmental Benefits of Reusable Modular Mass Timber Construction for Residential use in Japan: an LCA Approach.
China	2016–2025	MOHURD	https://www.mohurd.gov.cn/	Largest global modular construction program. Mandatory prefabrication quotas (up to 30–40% in major cities), green building rating system, and national construction waste recycling requirements.
	n.d.	BROAD Group Prefabricated modular construction and high-speed assembly case studies (T30 / modular building demonstrations)	https://www.broadgroup.com	HOLON modular system overview case study.
	2014	Zhang, X. et al (Journal of Cleaner Production)	Exploring the adoption of prefabricated construction in China	A study that identifies government incentives, technology, standardization, cost, and entrepreneurial cognition as key drivers for adopting prefabricated construction in China.

BY COUNTRY

Singapore	2014 – 2025	Building and Construction Authority (BCA)	https://www1.bca.gov.sg/	Global leader in mandated modular construction (PPVC). Strong recycled material requirements, strict waste minimisation, and advanced whole-life carbon building standards under Green Mark.
New Zealand	2022–2025	MBIE	https://www.mbie.govt.nz/	Introduces mandatory embodied carbon reporting and future caps. Encourages off-site construction, low-carbon materials, and increased circular economy integration in building procurement.
Sweden	2022	Boverket	https://www.boverket.se/en/	Mandatory upfront embodied carbon declaration for all new buildings. Strong circular construction culture, high timber modular adoption, and high recycling rates in steel and construction materials.
	n.d.	BoKlok	https://www.boklok.se	BoKlok official project information and housing concept.
Germany	2020–2023	BMWSB + DGNB	https://www.bmwsb.bund.de/	EU leader in circular construction systems. Requires lifecycle assessment, design-for-disassembly, material efficiency, recycled aggregates, and digital material passports for buildings.
France	2022	Ministry for Ecological Transition	https://www.ecologie.gouv.fr/	One of the strictest embodied carbon frameworks globally. RE2020 sets carbon limits for buildings; AGEC law mandates recycled material use, reuse targets, and construction waste recovery obligations.

United Kingdom	2022–2025	DLUHC + UK Government	https://www.gov.uk/	Transitioning toward mandatory whole-life carbon regulation. London requires circular economy statements and reuse-first design. Strong push toward net-zero-ready housing and low-carbon materials.
	2018	Waste House	U: https://wastehouse.org.uk/	A University of Brighton news article on updates to the Waste House — a permanent public building constructed almost entirely from discarded materials, including denim jeans, toothbrushes, DVD cases, and floppy discs used as wall-cavity insulation — reported as a live research and teaching project demonstrating circular-economy principles in construction.
	n.d.	Premier Modular	https://www.premiermodular.co.uk/case-study/bradfields-	Modular design of Bradfields Academy in Chatham, Kent in the UK.
United States	2021–2024	DOE + EPA + GSA	https://www.energy.gov/	Procurement-led decarbonisation system. Buy Clean policies require low-carbon steel, cement, and aluminium in public projects. Embodied carbon regulation still fragmented by state.
Canada	2022–2025	ECCC	https://www.canada.ca/en/environment-climate-change.html	Federal embodied carbon reduction through procurement. Provinces (BC, Quebec) leading modular housing uptake and recycled material integration into building codes.
The Netherlands	2026	Project OPZuid (Brightlands Chemelot Campus)	https://brightlandsmaterialscenter.com/projects/opzuid-circular-modular-housing/?utm_source=chatgpt.com	Circular modular housing project at the Brightlands Chemelot Campus delivered through a Limburg consortium, creating circular modular homes for social housing.
	2026	Appelweg – Built by nature	https://builtbn.org/nl/shortlisted-projects/appelweg/?utm_source=chatgpt.com	Appelweg provides a responsive blueprint for modular social housing in the form of a four-storey, 3,186 m² residential complex delivering 63 modular social housing units for Ymere housing corporation.

BY INDUSTRY

2025	Institution of Structural Engineers (UK)	https://www.istructe.org/resources/guidance/the-role-of-scrap-in-steel-decarbonisation/	The role of scrap in steel decarbonisation: Key facts and considerations for the construction sector. Guidance on specifying high-scrap steel and the limits of using recycled content as an emissions-reduction justification. Used to assess the embodied-carbon implications of increasing recycled steel content.
2025	Waste Transport Solutions	https://wastetransportsolutions.eu/plasterboard-recycling-in-europe-challenges/	*Plasterboard recycling in Europe: challenges and solutions* — Reports the gap between EU recycled gypsum availability and actual uptake in new plasterboard production.
n.d.	World Steel Association	https://worldsteel.org/about-steel/raw-materials/#scrap	Reference data on scrap utilisation ceilings for integrated steelmaking routes.
2025	Nucor Corporation (a)	2025 Corporate Social Responsibility Report	Corporate sustainability report outlining recycled content performance, scrap utilisation and decarbonisation initiatives across one of the world's largest steel manufacturers. Used to benchmark international best practice in recycled-content steel production.
2025	Nucor Corporation (b)	Recycled Content Letter	Product-specific declaration reporting recycled content across Nucor steel products. Used to benchmark achievable recycled-content levels for structural steel and reinforcing steel products and compare with Australian manufacturing practices.
2024	Norsk Hydro	Hydro CIRCAL®	Product information describing aluminium products manufactured with high levels of post-consumer recycled content. Used as an international benchmark for high recycled-content aluminium production and product verification.
2024	REGYP	https://regyp.com.au/waste/	*Plasterboard Waste*: describes Australia's plasterboard recycling infrastructure and network of specialist collection sites.
2024	Tomago Aluminium	Capral and Tomago Aluminium Agreement to Local Aluminium Remelting	Industry announcement outlining collaboration to establish local aluminium remelting capability and increase recycled aluminium content within Australian supply chains. Used to assess emerging domestic circular economy capability.

2024	USG Corporation	Sheetrock® Brand Gypsum Panels	Technical product information describing recycled paper facings, recycled gypsum content and environmental attributes of gypsum board products. Used as an international benchmark for recycled-content plasterboard products.
2023	Capral Aluminium	LocAl® Green Product Guide	Product guide outlining recycled-content aluminium billet options, embodied carbon performance and locally manufactured aluminium products. Used to assess recycled-content opportunities for aluminium window and door systems.
2023	CSR Gyprock	Environmental and Sustainability Information	Manufacturer sustainability information describing product stewardship initiatives, environmental performance and recycled content within Australian plasterboard manufacturing. Used to assess current industry capability and current recycled content performance.
2023	Ellen MacArthur Foundation	Circular design in the built environment	Provides circular economy frameworks and design principles for the built environment, focusing on eliminating waste, keeping materials in use, and designing out carbon from construction systems.
2023	Eurogypsum	https://eurogypsum.org/circularity-2923/	*Circularity* — European gypsum industry federation position on achievable recycled gypsum content in plasterboard (up to 30%).
2023	Knauf Gypsum Pty Ltd	Paving the Way for a Circular Economy: Knauf Gypsum Down Cycles 12,000 Tonnes of Plasterboard Waste	Industry case study outlining Knauf's plasterboard recycling initiatives and product stewardship program, demonstrating progress towards circular gypsum supply chains in Australia.
2023	Modular Building Institute	MBI Reports and Market Data	Industry reports outlining market growth, productivity benefits, and waste reduction performance of modular construction, particularly in North America, including increasing adoption of volumetric and panelised systems.
2023	Modular Building Institute	MBI Reports and Market Data	Industry reports outlining market growth, productivity benefits, and waste reduction performance of modular construction, particularly in North America, including increasing adoption of volumetric and panelised systems.
2023	World Steel Association	Steel Facts 2023	Global industry report providing benchmarks on steel production, recycling pathways and recycled steel inputs, including average recycled material use in EAF steelmaking.

2022–2024	Built Offsite Magazine	Built Offsite Publications	Ongoing industry publication providing insights into off-site and modular construction in Australia and internationally, including case studies, pilot programs, and global innovation trends in prefabrication.
2022	World Green Building Council	Circular Built Environment Report	Position paper linking circular economy strategies with green building goals, promoting lifecycle thinking, material reuse, and net-zero embodied carbon pathways in the construction sector.
2022	Nordic Ecolabelling	Nordic Swan Ecolabel Buildings Criteria	Type I ecolabelling system setting strict sustainability requirements for buildings, including limits on hazardous substances, energy performance, and minimum recycled and renewable material content.
2019	Arup	Arup Materials Research	Research on emerging sustainable construction materials, including bio-based, recycled, and low-carbon alternatives, supporting innovation in circular and regenerative design approaches.
2019	Modular Building Institute	MBI Industry Trends Report 2019	Earlier industry analysis highlighting modular construction efficiency, reduced construction waste, shorter project timelines, and increasing adoption across commercial and residential sectors.
n.d.	BlueScope Steel	https://steel.com.au/sustainability/climate-action/embodied-carbon-steel-products	*Embodied Carbon and Steel Products* — Manufacturer guidance on managing embodied carbon in steel specification given scrap-supply constraints.
n.d.	Trex	https://www.trex.com/why-trex/eco-friendly-decking/	*Trex recycled decking material* — Manufacturer information describing Trex's use of recycled plastic film and reclaimed wood in composite decking products, including cumulative recycled plastic volumes.
n.d.	TimberTech	https://www.timbertech.com/about/sustainability/	*Sustainable outdoor living solutions* — Manufacturer sustainability information reporting recycled content levels (approximately 65 to 85%) across TimberTech's composite decking product range.
n.d.	Eurima (European Insulation Manufacturers Association)	https://www.eurima.org/what-is-mineral-wool-insulation	Industry statements reporting mineral wool producers across Europe are using up to 60% recycled materials in their products.

n.d.	World Steel Association	https://worldsteel.org/steel-topics/sustainability/steel-recycling/	Industry data on post-consumer and pre-consumer recycled content shares in structural steel.
n.d.	ResponsibleSteel	https://www.responsiblesteel.org/	International certification standard for responsibly sourced steel, including verification of recycled content claims across supply chains.
n.d.	SteelConstruction.info	https://www.steelconstruction.info/Recycling_and_reuse	Industry guidance on structural steel recycling and reuse, reporting UK demolition recovery rates of 98–99%.
n.d.	Build Using Steel	https://www.buildusingsteel.co.uk/sustainability/	Industry sustainability guidance corroborating structural steel recovery rates exceeding 95% during demolition.
2024	InfraBuild	https://www.infrabuild.com/sustainability/environmental-product-declarations/	Environmental Product Declarations reporting recycled-content levels of 86.1–95.0% across EAF-manufactured reinforcing, merchant and structural steel products in the Australian market.
n.d.	Kings Research	https://www.kingsresearch.com/structural-steel-market-1107	Market research report on structural steel demand, supply and application within modular and volumetric construction.
n.d.	Hong Kong Construction Industry Council	https://mic.cic.hk/en/Events/39	Case study of the Nam Cheong 220 Modular Integrated Construction (MiC) project, designed for future relocation and enabling more than 95% structural steel reuse.
n.d.	Red & Black	https://www.redandblack.com/sponsored/recycled-steel-real-change-how-shipping-containers-are-shaping-green-construction/article_1d8bac2d-1f20-4457-9b2e-6dd781481c4f.html	Case study on the Mākhers Plug-In Pods modular housing concept in the United States, repurposing approximately 4 tonnes of shipping-container steel per dwelling.

n.d.	Tiny House Shadow	https://tinyhousetown.net/tiny-house-shadow/	Project description of a Finnish modular tiny-house incorporating reclaimed structural steel into prefabricated construction.
2023	World Economic Forum	https://www.weforum.org/stories/2023/01/davos23-steel-scrap-decarbonization/	Analysis estimating that recycled end-of-life scrap could supply approximately 44% of global steel demand by 2050, supporting expanded EAF production.
n.d.	OECD	Unlocking potential in the global scrap steel market | OECD	Policy analysis identifying expanded scrap collection, sorting and international recycling systems as a key pathway for steel-sector decarbonisation.
n.d.	Knauf	https://knauf.com/en-AU/sustainability/knauf-gypsum	Australian sustainability information confirming locally sourced gypsum and 100% recycled paper liners in Knauf plasterboard products.
n.d.	Knauf	https://knauf.com/en-AU/p/product/sheetrock-r-one-10mm-29949_055	SHEETROCK® ONE product page describing the board's 100% recycled paper liner.
n.d.	Knauf Insulation	https://knauf.com/en-GB/sustainability/knauf-insulation	Sustainability information confirming Knauf Insulation's Glass Mineral Wool contains up to 80% recycled content, and Rock Mineral Wool is manufactured using around 35% recycled content (mostly recycled glass cullet and steel-industry slag).
n.d.	USG Corporation	https://www.usg.com/en-US/p/product/sheetrock-brand-ecosmart-panels-firecode-x-141147	Product-specific page for Sheetrock® EcoSmart Firecode® X (up to 94.6% recycled content) — more specific than the generic USG entry already listed.
n.d.	Saint-Gobain / British Gypsum	https://www.british-gypsum.com/about-us/corporate-news-and-press-releases/british-gypsum-launches-100-recycled-plasterboard	Press release announcing Gyproc SoundBloc Infinaé 100, the first UK-manufactured plasterboard made from 100% recycled gypsum.

n.d.	Saint-Gobain	https://www.saint-gobain.com/sites/saint-gobain.com/files/media/document/20250116_plasterboard_VA.pdf	Corporate document referencing Saint-Gobain's 2022 French launch of plasterboard containing at least 50% recycled gypsum.
n.d.	Saint-Gobain Isover	https://www.isover-technical-insulation.com/glass-wool	Saint-Gobain's corporate brand page for ISOVER, its global glass wool insulation brand, describing the product's use of sand and recycled glass as core raw materials and outlining the company's insulation performance, sustainability commitments, and closed-loop recycling initiatives.
n.d.	Gyprock (CSR)	https://www.gyprock.com.au/contact-us/other/about-us/plasterboard-recycling	Product/company page on Gyprock's recycled paper liner content and manufacturing waste recovery rate (>95%). Possible overlap with the existing "CSR Gyprock — Environmental and Sustainability Information" entry — recommend confirming before adding as a duplicate line.
n.d.	Gyprock (CSR)	https://www.gyprock.com.au/products/residential-plasterboard/upgrade/hd	Product page for Gyprock HD, a 10mm plasterboard formulated to 10% recycled content.
n.d.	Gypsum Association	https://gypsum.org/recycling-gypsum-wallboard/	Industry guidance on gypsum wallboard recycling, construction scrap volumes (~12% of board used) and closed-loop recovery barriers.
n.d.	DCCEEW (Australian Government)	https://www.dcceew.gov.au/sites/default/files/env/pages/9014ac31-f832-48bd-85b9-f02d8ef70fbe/files/csr-gyprock.pdf	Case study on CSR Gyprock's take-back scheme, reporting ~1,400 tonnes/year diverted from landfill and contamination-acceptance criteria.
n.d.	Composite Panel Association	compositepanel.org	North American particleboard EPD reporting 92.44% wood residues by product composition.
n.d.	EGGER	egger.com	Manufacturer sustainability statement reporting.
n.d.	Uniboard	uniboard.com	Canadian particleboard environmental data sheet.
n.d.	Woodknowledge Wales	woodknowledge.wales (Kronospan circular	Case study on Kronospan Chirk.

n.d.	Kronospan	kronospan.com (UK EPD download)	Third-party verified EPD for melamine-faced particleboard.
n.d.	Kronospan	kronospan.com (Luxembourg news release)	Announcement of the first particleboard panel made entirely from 100% recycled wood.
n.d.	Pfleiderer	pfleiderer.com	Manufacturer data.
n.d.	European Panel Federation	europanels.org	Industry-level confirmation that recycled wood input is structurally compatible with particleboard manufacturing.
n.d.	Recycling Near You	https://recyclingnearyou.com.au/material/work/particleboard	Particleboard-specific recycling benchmark
n.d.	reDirect Recycling	https://www.redirectrecycling.com.au/wood-recycling/particleboard	Describes closed-loop particleboard recovery, with offcuts diverted and re-manufactured into new particleboard.
n.d.	RCOE / NSW Recycled Materials Guide	rcoe.com.au/circular-economy-resources/nsw-recycled-material-guide	Overview of the NSW Recycled Materials Guide as it applies to particleboard/engineered wood procurement.
n.d.	ModWood Sustainability	https://www.modwood.com.au/sustainability/	Sustainability page detailing recycled content composition.
n.d.	Ekodeck	https://ekodeck.com.au/sustainability/	Sustainability page detailing Ekodeck's reclaimed/recycled material content.
n.d.	Replas	https://www.replas.com.au/	Australian recycled-plastic manufacturer reporting a minimum of 85% recycled plastic content across products.
n.d.	EnviroBuild	https://www.envirobuild.com/products/hyperion-composite-decking	Product page for Hyperion Explorer composite decking, referencing EPD S-P-03566 verifying minimum 87% recycled content.
n.d.	Trex	https://icc-es.org/	ICC Evaluation Service listing supporting Trex's product-specific EPD and recycled-content verification.

n.d.	MoistureShield	https://www.moistureshield.com/why-moistureshield/sustainability/	Sustainability page detailing MoistureShield's 95% recycled content position.
n.d.	TimberTech Australia	https://www.timbertech.com.au/	Australian-market TimberTech site; distinct from the existing Appendix A entry for timbertech.com (US site), reporting 60–85% recycled content depending on product range.
2026	Hydro CIRCAL	https://www.hydro.com/en/global/aluminium/products/low-carbon-and-recycled-aluminium/low-carbon-aluminium/hydro-circal/ *htt*ps://www.hydro.com/en/global/about-hydro/publications-2026/certificates/	Hydro CIRCAL: Recycled aluminium with minimum 75% post-consumer scrap and verified low carbon footprint and Verification.
2025	US Aluminum Association	https://www.aluminum.org/building-construction	US trade association webpage outlining aluminium's role, market statistics, and sustainability credentials in the building and construction sector.
2026	Australian Aluminium Council / L.E.K. Consulting	https://aluminium.org.au/wp-content/uploads/2026/02/260305-Enabling-Development-of-Aluminium-Recycling-Capability-in-Australia.pdf	Report on Australia's vertically integrated aluminium sector, limited domestic remelt/recycling capability, and scrap export volumes.
n.d.	NuWool	https://nuwool.com/sustainability/	States the recycled content of Nu-Wool Premium Cellulose Insulation is 86%, with 65% of that being post-consumer recycled newspaper.
n.d.	NAIMA - North American Insulation Manufacturers Association (NAIMA)	https://insulationinstitute.org/im-a-building-or-facility-professional/insulating-air-handling-systems/codes-standards/	A technical resource page from NAIMA (the North American trade association for fibreglass and mineral wool insulation manufacturers), confirming that fibreglass insulation contains an average of 50% (up to 60%) recycled glass, alongside broader codes and standards guidance for insulation professionals.

EPDs

2022	FWPA (Forest and Wood Products Australia)	Softwood Timber Industry EPD	FWPA - Softwood Timber Industry EPD
2024	Knauf	WETSTOP™ 10mm Plasterboard EPD	Knauf Wetstop 10mm EPD
2024	Knauf	SHEETROCK® ONE 10mm Plasterboard EPD	Knauf Sheetrock One 10mm EPD
2024	Knauf	SHEETROCK® HD 13mm Plasterboard EPD	Knauf Sheetrock HD 13mm EPD
2024	Weathertex	Primed Flat Sheet and Weatherboard EPD	Weathertex Primed Flat sheet and weatherboard EPD
2026	Cemintel	Cemintel EPD (Paint on Site)	Cemintel EPD
2026	CIMA - Cellulose Insulation Manufacturers Association	Loose-Fill Cellulose Insulation	https://cellulose.org/wp-content/uploads/2026/04/CIMA-EPD-for-Loose-Fill-Cellulose-Insulation.pdf
n.d.	BlueScope	GALVASPAN® Steel EPD	Bluescope - Galvaspan steel
n.d.	BlueScope	TRUECORE® Steel EPD	Bluescope - TRUECORE Steel
n.d.	James Hardie	Fibre Cement Products EPD	James Hardie Fibre Cement Products EPD
n.d.	Knauf Insulation	Glasswool with ECOSE® Technology EPD	Knauf Insulation EPD
n.d.	Porta / Polytec	Particleboard EPD	Porta / Polytec EPD

Appendix B: Case Studies Profiles for Literature Review Activity

This appendix provides brief profiles of selected international case studies of circular modular or prefabricated housing, grouped by region.

Australasia (Australia & New Zealand)

- **Legacy Living Lab (Western Australia, 2020):** A two-storey modular prototype building (approx. 250 m^2 mixed-use space) designed for disassembly and high recycled content. It used eight steel-framed modules bolted together, with 73% of the steel structure composed of reclaimed sections and various reclaimed interior elements. The project's LCA found ~60% reduction in embodied GHG emissions versus a comparable new-build (largely thanks to reused steel) and 88% lower emissions when compared to a scenario of demolishing and recycling the materials. The building can be fully disassembled and reassembled; it currently serves as a demonstration "living lab" for sustainable building technologies.

- **ATCO Modular Building Systems (Australia, ongoing):** An organisation-level case study of ATCO's Australian operations (second-largest prefab manufacturer in the country) demonstrated modular construction's benefits. ATCO's data showed construction schedules 40% shorter and on-site labour costs ~25% lower for modular vs traditional projects and cited evidence (via WRAP) that off-site construction can achieve up to 90% reduction in on-site construction waste.

- **Auckland Volumetric Timber Housing (New Zealand, 2021):** A public housing project delivering over 100 apartments with volumetric Cross-Laminated Timber (CLT) modules, achieving rapid onsite assembly (cutting construction time by ~35%) and virtually zero waste generated in the factory (a major NZ manufacturer reported sending no production waste to landfill). The use of renewable timber structure and minimal waste approach significantly lowered embodied carbon – the project was estimated to avoid ~20–30% of GHG emissions relative to a concrete building, and is aligned with New Zealand's new ``Building for Climate Change'' objectives to encourage low-carbon materials.

North America (United States & Canada)

- **Fortress Obetz (USA, 2019):** A large 8,000 m^2 sports complex in Ohio constructed from reused shipping containers, showcasing adaptive reuse of steel modules. The project repurposed 122 shipping container units, cutting both construction time (open in 14 months) and material use – an estimated reduction of 129 tonnes of steel compared to new build. The design is modular, allowing disassembly of sections if needed, and local authorities supported it as a pilot for container-based construction (MBI, 2020).

- **Reclaimed Modular Classrooms (USA, 2025):** Wernick Group's refurbished modular classroom buildings (36-module blocks) in the UK were assessed by an academic study when re-deployed, finding a 46% reduction in embodied carbon compared to equivalent new construction due to the reuse of structural elements. This model – leasing and refurbishing used modules – is also relevant to the US and Canada, where some companies specialise in renovating old modular units for new uses, thereby avoiding production of new materials.[4]
- **Vancouver Affordable Housing (Canada, 2022):** A partnership between BC Housing and Metric Modular delivered 44 apartments using volumetric steel modules under Canada's Rapid Housing Initiative, demonstrating how modular can achieve fast delivery (under 5 months from design to occupancy) for affordable housing with good sustainability performance (Step Code 4 energy efficiency). The embodied carbon of the project was analysed and found to be roughly 7% lower than an equivalent conventional build, with over 90% of construction waste diverted from landfill via factory recycling (BC Housing, 2023). Key enablers were significant public funding and streamlined approvals, whereas barriers included initial higher costs and limited familiarity of local trades with modular systems.

Europe (including UK)

- **Recygénie Housing, Gennevilliers (France, 2024):** A 220-unit social housing project that is the world's first building made entirely of recycled concrete (Holcim ECOCycle technology). This six-storey building used a custom concrete mix with 100% recycled cement and aggregates, saving over 6,000 tonnes of natural resources. The project demonstrates that even structural materials can attain very high recycled content given innovative partnerships (Holcim and a public housing developer) and targeted technical assessments (the project obtained special approvals to use the experimental concrete). It achieved performance comparable to conventional concrete and is intended to influence French regulations toward mandatory minimum recycled content in concrete. (WEF_PR199_Innovative_Practice_Recygenie_2024.pdf)

- **Circle House (Denmark, 2020):** A pilot apartment complex of 60 social housing units built with comprehensive design for deconstruction strategies (bolted connections, reversible materials). It is documented that 90% of building components can be reused or recycled at end-of-life (e.g. concrete elements are bolted, not grouted, to allow separation) (Leising et al., 2018). The project is also notable for its collaborative approach – over 60 partners (architects, engineers, suppliers) were involved to align design, contract and logistics for future disassembly. The initiative uncovered challenges around current insurance and liability frameworks for reused components, suggesting that supporting mechanisms (standards, warranties) are needed to fully commercialise such projects.

***4 Source**: WRB-technical-report-1.pdf*
***5 Source:** WEF_PR199_Innovative_Practice_Recygenie_2024.pdf*

- **Wernick Refurbished Module (UK, 2025):** An academic study of a refurbished 8-module building by Wernick (UK) quantified the carbon benefits of reusing modular units. By relocating and refurbishing an 8-module building (originally a school building) instead of constructing a new one, the project achieved 46% less embodied carbon relative to a new build equivalent, thanks mainly to reusing the steel structure. The refurbished modules also generated far less waste than new construction – essentially only minor renovation debris and no structural waste, as the steel modules were reused in situ. The UK context shows that circular business models for modular construction (leasing, retrieving and refurbishing modules) can yield both environmental benefits and cost savings (avoiding new material costs and disposal fees).

- **BoKlok Volumetric Housing (Sweden, 2010s–present):** BoKlok, a joint venture of Skanska and IKEA, has delivered over 13,000 affordable homes using timber modular construction. While not explicitly a "circular economy" programme, BoKlok's approach naturally incorporates many circular aspects: standardised design for flexibility, the use of renewable FSC-certified timber, and factory processes that achieve over 90% waste recycling. BoKlok homes have ~50% lower lifecycle carbon footprint than comparable conventional houses, due in large part to using timber instead of steel or concrete and minimising waste through optimised prefab processes (BoKlok, 2022). The scheme shows how scaling up sustainable modular housing can yield both affordability and sustainability gains.

Asia

- **Long-Life Reusable Modular Timber (Japan, 2019):** Reusable Modular Mass Timber (RMMT) is a concept design for small urban houses using modular cross-laminated timber elements and a leasing model. The design envisions CLT modules that can be demounted with minimal damage (all connections via screws) and reused for a second 30-year cycle. Simulated LCA results showed up to ~75% reduction in life-cycle carbon when modules were reused for a second life, even after accounting for impacts of refurbishment (Novais Passarelli et al., 2019). The project won an international design award and influenced research on product-service models for housing in Japan.

- **MiC High-Rise Pilot (Hong Kong, 2021):** A pilot Modular Integrated Construction (MiC) project in Hong Kong tested a multi-storey concrete volumetric system designed for high-density cities. The project achieved a 20.7% reduction in embodied carbon compared to a traditional baseline through measures including optimised modular design, reduced material waste, and use of some recycled aggregates in concrete (Development Bureau Hong Kong, 2021). The MiC system also reduced construction time by 30% and demonstrated improved quality and labour safety. The case underscores the value of government support (the Hong Kong authorities provided R&D funding and fast-tracked approvals for this pilot) in overcoming initial barriers and validating new methods in a local context.

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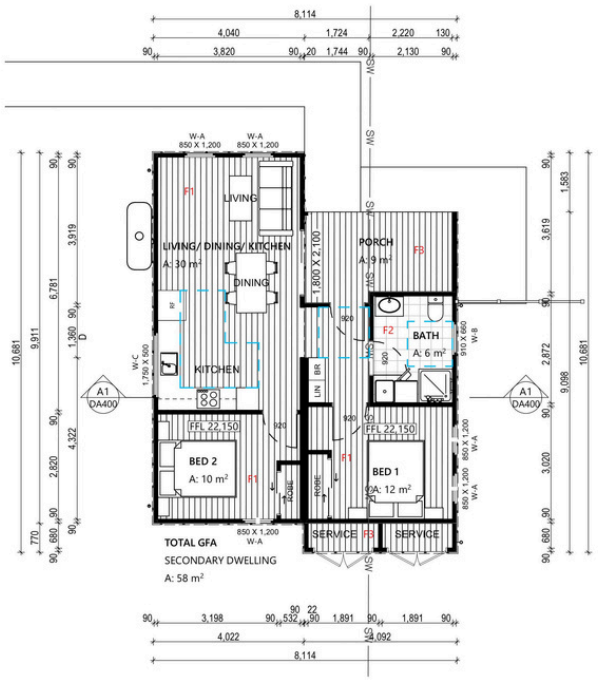
Appendix C: MOOV modular dwelling – Architectural Drawings and Floor Plan



AREA CALCULATION (m2)		
	DEEP SOIL	227.40
	LANDSCAPING	268.05
BATH		6.01
BED 1		11.55
BED 2		10.45
LIVING/ DINING/ KITCHEN		30.36
PORCH		8.89
TOTAL GFA (EXCLUDING PORCH, DECK AND SERVICES)	PRIMARY DWELLING	75.75
	SECONDARY DWELLING	58.39

Floor Finishes

F1 - Vinyl
Living/Kitchen, Hallway, Entry, Bedrooms
High quality Vinyl
Composite decking
Colour: Light brown

F2 - Tiling
Bathroom
300x300 Textured Floor Tiles
Slip resistant P4
Colour: Light grey

F3 - Decking:
External decks, services rooms
Multiwood
Composite decking
Colour: Light brown

Wall finishes

Living areas and Bedrooms
13mm Plasterboard
Painted, Colour: Natural White

Bathroom
300x600 Wall tiling
Wall to Ceiling
White

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Project Status	FOR CONSTRUCTION
Client	NSW LAND AND HOUSING COORPORATION
Climate Zone	56 MASCOT (SYDNEY AIRPORT)
Site:	

DRAWING TITLE :
FLOOR PLANS
GROUND FLOOR

PROJECT NAME :
Homes NSW Tranche 3

N

ISSUE	DESCRIPTION	DATE
P1	Transmittal Set	24/10/2025
A	Development Application	7/1/2025
C	For CONSTRUCTION	20/01/2026

REVISION NO. C
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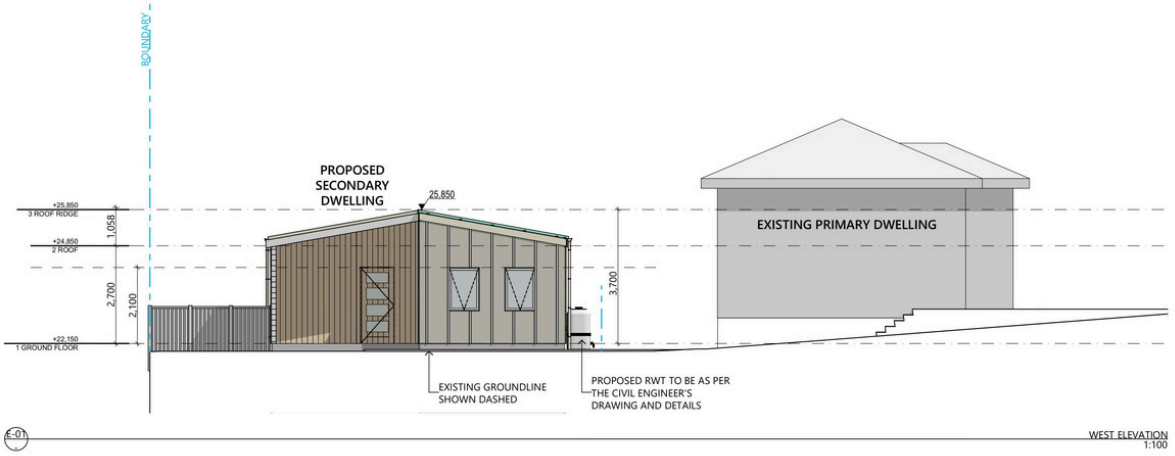
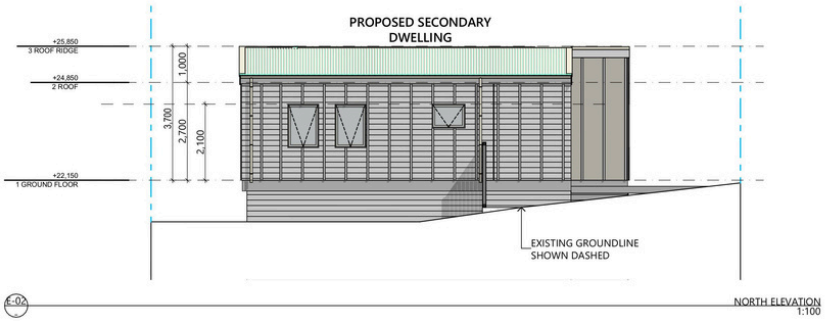
DRAWING NO. DA110
Drawn | Checked RR | IM





ELEVATION NOTES

1. REFER TO EXTERNAL FINISHES FOR SELECTED MATERIALS AND COLOURS
2. REFER TO CONSULTING ENGINEERS DRAWINGS FOR STORMWATER DETAILS
3. FOR ROADWAY, DRIVEWAY AND RETAINING WALL DESIGN & LEVELS REFER TO CIVIL ENGINEERS DOCUMENTATION
4. DOWNPIPE POSITIONS ARE INDICATIVE ONLY, POSITION OF DOWNPIPES TO BE CONFIRMED BY BUILDER.
5. FOR LANDSCAPE DESIGN & FENCE LOCATIONS REFER TO LANDSCAPE DESIGNERS DOCUMENTATION

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Project Status	FOR CONSTRUCTION
Client	NSW LAND AND HOUSING COORPORATION
Climate Zone	56 MASCOT (SYDNEY AIRPORT)
Site:	

DRAWING TITLE :
ELEVATIONS
ELEVATIONS

PROJECT NAME :
Homes NSW Tranche 3

ISSUE	DESCRIPTION	DATE
P1	Transmittal Set	24/10/2025
A	Development Application	7/11/2025
C	For CONSTRUCTION	20/01/2026

REVISION NO. **C**
SCALE **1:100**
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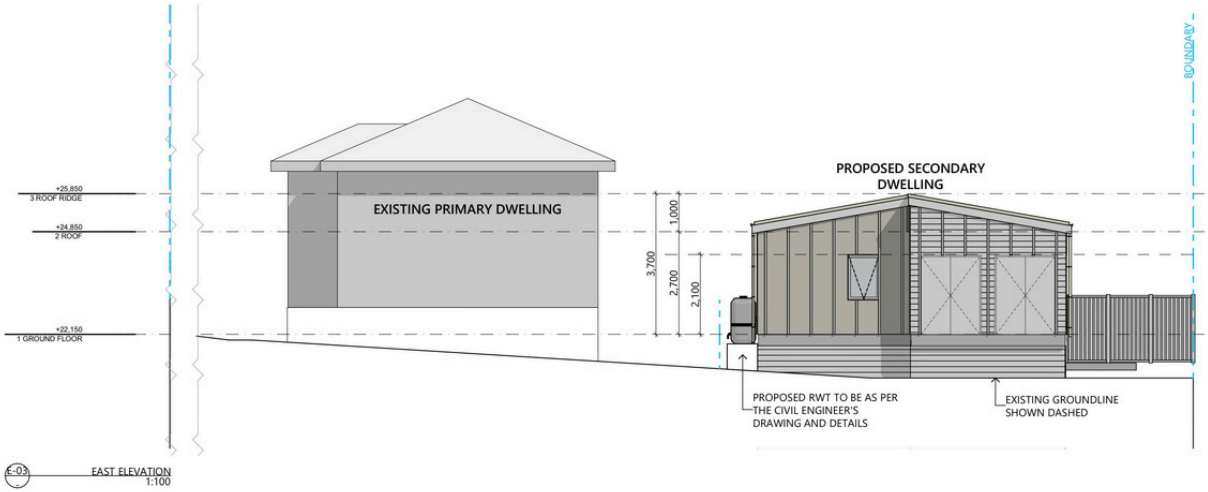
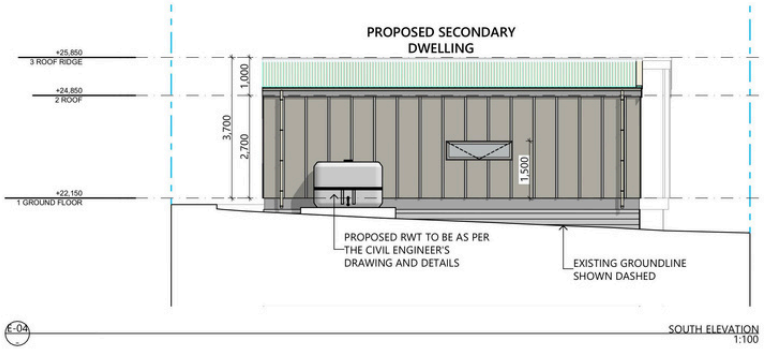
Drawn | Checked **RR | IM**





ELEVATION NOTES

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Project Status	FOR CONSTRUCTION
Client	NSW LAND AND HOUSING COORPORATION
Climate Zone	56 MASCOT (SYDNEY AIRPORT)
Site:	

DRAWING TITLE :
ELEVATIONS
ELEVATIONS

PROJECT NAME :
Homes NSW Tranche 3

ISSUE	DESCRIPTION	DATE
P1	Transmittal Set	24/10/2025
A	Development Application	7/11/2025
C	For CONSTRUCTION	20/01/2026

REVISION NO. **C**
SCALE **1:100**
DRAWING NO. **DA301**
Drawn | Checked **RR | IM**





TIMBERLOOK VERTICAL CLADDING

BATTEN - OYSTER

JAMES HARDIE EASYPANEL CLADDING - OYSTER

WEATHERTEX VGROOVE 150mm CLADDING - WHISPER WHITE

ROOF - COLOURBOND SHALE GREY

BATTEN - WHISPER WHITE

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Project Status	FOR CONSTRUCTION
Client	NSW LAND AND HOUSING COORPORATION
Climate Zone	56 MASCOT (SYDNEY AIRPORT)
Site:	

DRAWING TITLE :

ELEVATIONS

EXTERNAL FINISHES

PROJECT NAME :

Homes NSW Tranche 3

ISSUE	DESCRIPTION	DATE
P1	Transmittal Set	24/10/2025
A	Development Application	7/11/2025
C	For CONSTRUCTION	20/01/2026

REVISION NO. **C**

SCALE **1:50**

DRAWING NO. **DA350**

Drawn | Checked **RR | IM**

Appendix D: Data Collection and Verification Framework Table

STEP 3 — MATERIALS / BOQ SUMMARY

For each material or product used in the nominated modular housing project, complete one row below. Columns A–G are material identity and usage. Columns H–P capture the recycled content claim, chain of custody and shipment details for the RC Verification tab. Add additional rows as needed.

Material Identity & Usage (Step 3a — Material Details)									Recycled Content Verification (Step 3b — RC Verification)							
#	Material Category	Supplier name	Manufacturer	Material / Product name	Description / Component label	Application in Project	Total weight	% of hole house weight	Recycled content claimed?	Pre-consumer Recycled (%)	Post-consumer Recycled (%)	Total Recycled Content (%)	Chain of custody approach	Australian-sourced recycled content?	Evidence type	PCF / EPD / Certification URL
	e.g. Timber/board	e.g. Smith & Co Ltd	detail	e.g. 10mm particleboard	e.g. Benchtop, frame, door	Flooring/joinery/wall panel	kg	7 Tonne per module (crane record). Total weight 14 000	Yes/No/Unknown	% pre-consumer recycled content	% post-consumer recycled content	% total recycled content	Mass balance / Controlled blending / Segregation / Identity preservation / Unknown	Yes / No / Unknown (e.g. Australia / China /)	EPD / declaration / certificate / self-declared	e.g. www.epdaustralasia / 12345
1	Steel	Stratco	BlueScope - Link 1	MAXI C-SECTION 300 3.0 PUNCHED, FLOOR JOIST 182 2.4	Steel floor base	Flooring	1651.05	11.79	Yes	0% (6.8% reported as intrenal scrap cannot be considered as	17.4%	17.4%	Mass balance (providing average recycled content data on an annual basis; based on detailed production data)	BlueScope largely meets its scrap requirements domestically. There have been rare instances where we have had to	EPD / Recycled content statement	https://epd-australasia.com/wp-content/uploads/2023/08/SP09341-Bluescope-EPD-GALVASPAN_Jul23.pdf
2	Steel	AusSteel	BlueScope - Link 2	TRUECORE steel G550, Hot-dipped galvanised	Steel frame	Framing	1240.1	8.86	Yes	0.0%	17.4%	17.4%	Mass balance (providing average recycled content data on an annual basis; based on detailed production data)	BlueScope largely meets its scrap requirements domestically. There have been rare instances where we have had to	EPD / Recycled content statement	https://epd-australasia.com/wp-content/uploads/2023/06/SP08455-Bluescope-EPD_Truecore_May23.pdf
3	Board	Australian Panels Products	Porta	Structaflor RedTongue 22mm 3600x800	Structural flooring	Flooring	985.74615	7.04	Yes			40%	Volume Credit	Yes	EPD, Global Green Tag Greenrate Level A, PEFC/RW. For recycled content we currently	https://www.polytec.com.au/docs/technicalipolytec-technical-ecospecifier-green-tag-pr-p
4	Board	Campbell Building Materials	James Hardies	Hardie™ Secura™ Flooring	Structural wet area flooring (from pre-purchased stock)	Flooring	175.8	1.26	No	0-4%	0	0-4%	Unknown	Yes	EPD/Self Declared	https://www.jameshardie.com.au/ContentfulCMS/Technical-Library/Environmental_Produc
5	Fibreglass / Insulation	Knauf	Knauf	R2.7 Wall Batt 90x0580x01160	Insulation	External wall	268.91	1.92								https://knauf.com/en-AU/tools/download-center?division%5B0%5D
	Fibreglass / Insulation	Knauf	Knauf	R2.7 Wall batt 90x430x1160	Insulation	External wall	28.8	0.21								
	Fibreglass / Insulation	Knauf	Knauf	R2.5 Wall Batt 90x0580x01160 UF12(5)	Insulation	Internal walls	87.012	0.62								https://knauf.com/en-AU/tools/download-cent

STEP 3 — MATERIALS / BOQ SUMMARY

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Material Identity & Usage (Step 3a — Material Details)									Recycled Content Verification (Step 3b — RC Verification)							
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	e.g. Timber/board	e.g. Smith & Co Ltd	detail	e.g. 10mm particleboard	e.g. Benchtop, frame, door	Flooring/joinery/wall panel	kg	7 Tonne per module (crane record). Total weight 14 000	Yes/No/Unknown	% pre-consumer recycled content	% post-consumer recycled content	% total recycled content	Mass balance / Controlled blending / Segregation / Identity preservation / Unknown	Yes / No / Unknown (e.g. Australia / China /)	EPD / declaration / certificate / self-declared	e.g. www.epdaustralasia / 12345
	Fibreglass / Insulation	Knauf	Knauf	R6.0 Ceiling Batt 275x0580x01160	Insulation	Ceiling	174.72	1.25	Yes	No mention	75-100%	40-80% Recycled Glass 66% (2023 number)			EPD-IES-0002501:001	er?division%5B0%5D https://www.environdec.com/library/epd2501
	Fibreglass / Insulation	Knauf	Knauf	R2.5HD Wall Batt 90x0580x01160	Insulation	Flooring	116.91	0.84	Yes	No mention	75-100%	40-80% Recycled Glass 66% (2023 number)			EPD-IES-0015885	https://www.environdec.com/library/epd15885
6	Insulation	Stratco	Kingspan	PERMICAV XV 1350X22.25M 30M2 - KINGS	Aircell	Flooring	16.6272	0.12	No	0	0	0				
7	Insulation	Premier Commercial Insulation	CSR / Bradford	Enviroseal RW 3000x25m Enviroseal Aero Wrap 1350x30m 40.5m2	Wall wrap - Enviroseal	Walls	13.95495	0.10	Yes	No mention	72-76%	72-76% (80% recycled glass)			EPD	https://epd-australasia.com/epd/bradford-ceiling-wall-floor-products-
8	Timber	Campbell Building Materials	Hyne timber or other suppliers	H2 RAD FRAMING 070X035	Timber battens (cavity)	Walls	469	3.35	No				AS 4707:2021 Chain of Custody of Forest Products Physical Separation (Segregation) Percentage Method (Mass	no	EPD / COC	https://cdn.prod.website-files.com/630d8e3d270550dd26295c06/63c4f32556be052920b74fa1_qViP3pul3upVH3Z1RceD_dR-3OJF_ID
	Timber	Campbell Building Materials	Hyne timber or other suppliers	H3 RAD F/J P/P 066X018 EXT	Timber feature battens	Walls	154	1.10	No				AS 4707:2021 Chain of Custody of Forest Products Physical Separation (Segregation) Percentage Method (Mass	no	EPD / COC	https://cdn.prod.website-files.com/630d8e3d270550dd26295c06/63c4f32556be052920b74fa1_qViP3pul3upVH3Z1RceD_dR-3OJF_ID

STEP 3 — MATERIALS / BOQ SUMMARY

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Material Identity & Usage (Step 3a — Material Details)									Recycled Content Verification (Step 3b — RC Verification)							
#	Material Category	Supplier name	Manufacturer	Material / Product name	Description / Component label	Application in Project	Total weight	% of hole house weight	Recycled content claimed?	Pre-consumer Recycled (%)	Post-consumer Recycled (%)	Total Recycled Content (%)	Chain of custody approach	Australian-sourced recycled content?	Evidence type	PCF / EPD / Certification URL
	e.g. Timber/board	e.g. Smith & Co Ltd	detail	e.g. 10mm particleboard	e.g. Benchtop, fram door	Flooring/joinery/wa panel	kg	7 Tonne pe module (cran record). Total weight 14 000	Yes/No/Unknow	% pre-consume recycled conten	% post-consum recycled conten	% total recycle content	Mass balance / Controlled blending / Segregation / Identity preservation / Unknown	Yes / No / Unknown (e.g. Australia / China /	EPD / declaration / certificate / self-declare	e.g. www.epdaustralasia / 12345
													Products Physical Separation (Segregation) Percentage Method (Mass			7055088262956b63c4f32556be052920b74fa1_qVlP3pul3upVH3Z1RceD dR-3OJF ID
	Timber	Campbell Building Materials	Hyne timber or other suppliers	H3 RAD F/J P/P 188X018	Jambs for service room doors	Doors / framing	44	0.31								
9	Board	Campbell Building Materials	Weathertex	WTEX SELFLOK V GROOVE SMOOTH 150MM 3660X300MM	Cladding	Walls	396.1	2.83	No							https://weathertex.com.au/accreditations-certificates/
10	Board	Knauf	James Hardies	Easylap Panel	Cladding	Walls	673.2	4.81	No	0-4%	0	0-4%	Unknown	Yes	EPD / Self Declared	https://www.jameshardie.com.au/ContentfulCMS/Technical-Library/
11	Board	CSR	Cemintel	Territory Woodlands Birch 16mm 455mm x 3030mm	Cladding	Walls	254.6	1.82	No		0%	0%			EPD	https://epd-australasia.com/epd/cemintel-prefinished-fibre-cement-pr
	Board	Campbell Building Materials	James Hardies	FC Sheeting - Hardiflex - 4.5mm thick	Eaves lining on porch and service rooms	Roofing	72	0.51	No	0-4%	0	0-4%	Unknown	Yes	EPD / Self Declared	https://www.jameshardie.com.au/ContentfulCMS/Technical-Library/
	Board	Campbell Building Materials	James Hardies	FC Sheeting - Hardiflex - 6mm thick	Service rooms wall lining	Walls	141.75	1.01								
12	Glazing / Metal	Bradnams	Glazing: Glass Works Australia	Glazing	Aluminium windows and doors	Windows	160	1.14								

STEP 3 — MATERIALS / BOQ SUMMARY

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	e.g. Timber/board	e.g. Smith & Co Ltd	detail	e.g. 10mm particleboard	e.g. Benchtop, fram door	Flooring/joinery/wa panel	kg	7 Tonne pe module (cran record). Total weight 14 000	Yes/No/Unknow	% pre-consume recycled conten	% post-consum recycled conten	% total recycle content	Mass balance / Controlled blending / Segregation / Identity preservation / Unknown	Yes / No / Unknown (e.g. Australia / China /	EPD / declaration / certificate / self-declare	e.g. www.epdaustralasia / 12345
12	Glazing / Metal	Bradnams	**Aluminium:** National Aluminium	Aluminium framing for windows and doors	Aluminium windows and doors	Windows	149	1.06	Aluminium: No	Aluminium: 0% 7% (based on Rio Tinto NZAS	Aluminium: 0%	Aluminium: 0%	Aluminium: Log produced at upstream smelter receive cast identification for traceability	Aluminium: 0%		
12	Glazing / Metal	Bradnams	**Plastics:** Queensland Plastics	Glazing, Aluminium framing	Aluminium windows and doors - **seals etc**	Windows	minor weight									
12	Glazing / Metal	Bradnams	**Hardware:** Doric	Glazing, Aluminium framing	Aluminium windows and doors - **Handles and locks**	Windows	minor weight									
13	Metal	Stratco	Bluescope	Superdek 0.48mm (Colourbond)	Roof sheeting and flashings	Roofing	630	4.50	Yes	0.0%	17.4%	17.4%	Mass balance (providing average recycled content data on an annual basis; based on	BlueScope largely meets its scrap requirements domestically. There have	EPD / Recycled content statement	https://cdn.dcs.bluescope.com.au/download/environmental-product
15	Board	Knauf	Knauf	SHEETROCK® ONE 13MM (different sheet sizes)	High Density Wall and Ceiling Plasterboard	Walls	1241.85	8.87	Yes	2.26–5.87%		2.26–5.87%			EPD. GECA certified	https://knauf.com/api/download-center/v1/assets/009efa17-b037-4e
	Board	Knauf	Knauf	SHEETROCK® ONE 10MM 10x1200x6000mm	Plasterboard - 10mm	Ceiling	383.205	2.74	Yes	2.26–5.87%		2.26–5.87%			EPD	https://knauf.com/api/download-center/v1/assets/ac43ce29-0ec5-4d
16	Board	Knauf	Knauf	WETSTOP™ 13mm 13x1350x3000mm	Water resistant plasterboard (Wet area wall	Walls	229.08	1.64	Yes	2.26–5.87%		2.26–5.87%			EPD. GECA certified	https://knauf.com/api/download-center/v1/assets/ac43ce29-0ec5-4d

STEP 3 — MATERIALS / BOQ SUMMARY

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	e.g. Timber/board	e.g. Smith & Co Ltd	detail	e.g. 10mm particleboard	e.g. Benchtop, fram door	Flooring/joinery/wa panel	kg	7 Tonne pe module (cran record). Total weight 14 000	Yes/No/Unknow	% pre-consume recycled conten	% post-consum recycled conten	% total recycle content	Mass balance / Controlled blending / Segregation / Iden preservation / Unknown	Yes / No / Unknown (e.g. Australia / China /	EPD / declaration / certificate / self-declar	e.g. www.epdaustralias / 12345
17	Foam board (custom produced)	Mitre 10	Multipanel	Multipanel	Waterproof foam board, used instead of screed in wet area	Waterproofing / Flooring		TBC	Yes	upplier end as portion of that has recycled chemicals -to be confirmed						
20	Board	Flooring Extra / Campbells	Intafloors > Manufacturer	structural Plywood 7mm	Plywood (under vinyl, frame bracing)	Flooring, Walls	99.541	0.71								
21	Timber	Campbell Building Materials	Hume / Timber supplier?	RAD INT PENCIL RND 090X018	Architraves and Skirting, wardrobe jambs	Walls	117	0.84								
22	Board	Galley Kitchens	Porta	33mm particle board with Polytec Laminate	Kitchen Joinery	Benchtop		TBC	Yes			40%	Volume Credit	Yes	EPD, Global Green Tag Greenrate Level A, PEFC/RW. For recycled	GreenRate Certificate, https://www.polytec.com.au/docs/technical/p
	Board	Galley Kitchens	Porta	16mm thick particle board carcass, 16mm MDF door panels	Kitchen Joinery	Cabinet joinery	Estimated 1200 kg total	8.57	No	0%	0%	0%	N/A	N/A	EPD, Global Green Tag Greenrate Level A, PEFC/RW	https://www.polytec.com.au/docs/technical/polytec-technical-ecospecifier-green-tag-e0-st
23	Board	Factory Direct Wardrobes	Porta	16mm thick particle board carcass	Wardrobe and linen joinery	Joinery	271	1.94	Yes			40%	Volume Credit	Yes	EPD, Global Green Tag Greenrate Level A, PEFC/RW. For recycled	GreenRate Certificate, https://www.polytec.com.au/docs/technical/p
24	Door	Campbell Building Materials	Hume / Timber supplier?	DOOR STPC BLOCKBOARD DURAXP 2100X920X40	Internal doors	Doors	estimated 180kg									
	Steel door frame	Campbell Building Materials	Hume / Steel Supplier?	Custom profile steel door frame	Internal and external doors, linen cupboard	Doors / framing	Estimated 450kg	3.21								

STEP 3 — MATERIALS / BOQ SUMMARY

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	e.g. Timber/board	e.g. Smith & Co Ltd	detail	e.g. 10mm particleboard	e.g. Benchtop, fram door	Flooring/joinery/wa panel	kg	7 Tonne pe module (cran record). Total weight 14 000	Yes/No/Unknow	% pre-consume recycled conten	% post-consum recycled conten	% total recycle content	Mass balance / Controlled blending / Segregation / Iden preservation / Unknown	Yes / No / Unknown (e.g. Australia / China /	EPD / declaration / certificate / self-declar	e.g. www.epdaustralias / 12345
25	Composite	Stratco	Modwood	MODWOOD XTG 137x23 GRVD SB 5.4M 20 GROOVED SANDY BAY	Decking boards	Decking / Flooring	431.2	3.08	Yes	55%	30%	Greater than 85%		Australia	declaration	
26	Blinds	Flooring Extra	Manufacturer	Fabric - Vibe Colour - Terrace	Roller blinds	Blinds										
27	Vinyl	Flooring Extra	Manufacturer	"Sovereign " vinyl planks	Vinyl Flooring	Flooring	261.95	1.87								
28	Fit off items	Eagles Plumbing	Manufacturer	Taps and mixers, towel rails, toilet paper roll holder	Fit off	Fit off										
29	Stainless steel	Eagles Plumbing	Manufacturer	Stainless steel sink	Sink	Plumbing / Joinery										
30	Paint	Sneddon Painting	Henry Haymes													
31	Tiles	My Tile and Co	Manufacturer	Wall tiles 300x600 Wall tiles 300x300 Splashback tiles - 149x600	Tiling	Floors and walls	584.79	4.18								
	Tiles	My Tile and Co	Ardex	Ardex Misty Grey grout Ardex white grout	Tiling	Floors and walls										

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	e.g. Timber/board	e.g. Smith & Co Ltd	detail	e.g. 10mm particleboard	e.g. Benchtop, frame, door	Flooring/joinery/wall panel	kg	7 Tonne per module (crane record). Total weight 14 000	Yes/No/Unknown	% pre-consumer recycled content	% post-consumer recycled content	% total recycled content	Mass balance / Controlled blending / Segregation / Identity preservation / Unknown	Yes / No / Unknown (e.g. Australia / China /	EPD / declaration / certificate / self-declared	e.g. www.epdaustraliasia / 12345
32	Glazing / Aluminium	Exclusive Glass	Manufacturer	Shower Screen												
33	Aluminium	Glass outlet	Manufacturer	Handrails and Screening under modules												
34	Waterproofing	My Waterproofing Co	Ardex	Ardex WPM300 - Primer Arder WPM155 - Waterproofing	Waterproofing	Flooring	7.96	0.06	Documents from online downloaded							
							Total wight recorded (%)	94.15								

STEP 3 — MATERIALS / BOQ SUMMARY

List all packaging materials used to ship modules or major materials to the project/customer, where known. (e.g. cardboard box, plastic wrap, timber pallet). Complete the same columns as above.

Packaging Identity & Usage									Recycled Content Verification							
#	Material Category	Supplier name		Material / Product name	Description / Component label	Application in Project			Recycled content claimed?	Pre-consumer Recycled (%)	Post-consumer Recycled (%)	Total Recycled Content (%)	Chain of custody approach	Australian-sourced recycled content?	Evidence type	PCF / EPD / Certification URL
	e.g. Timber/board	e.g. Smith & Co Pty Ltd		e.g. 10mm particleboard	e.g. Benchtop, frame, door	Flooring/joinery/wall panel			Yes/No/Unknown	% pre-consumer recycled content	% post-consumer recycled content	% total recycled content	Mass balance / Controlled blending / Segregation /	Yes / No / Unknown (e.g. Australia / China /	EPD / declaration / certificate / self-declared	e.g. www.epdaustraliasia /
1	Pallet	James Hardies			Hardie Secura Flooring & Easylap panels are supplied on pallets	Packaging			No			0%	Unkown	No	EPD / Self Declared	https://www.jameshardie.com.au/ContentfulCMS/Technical-Library/
2	Plastic wrap	James Hardies				Packaging			No			0%	Unkown	No	EPD / Self Declared	https://www.jameshardie.com.au/ContentfulCMS/Technical-Library/
3	Cardboard	James Hardies				Packaging			No			0%	Unkown	No	EPD / Self Declared	https://www.jameshardie.com.au/ContentfulCMS/Technical-Library/
4	Timber gluts	ITI AUS	(Modwood)			5 kgs per pack of decking										
5	Plastic wrap	Allviron	(Modwood)										Australia	yes		
6	MDF	Kastoria	(Modwood)										Australia			
7	Stretch wrap LLDPE	CSR	Cemintel								<1%					
8	Polyester batts LDPE	CSR	Cemintel								<4%					

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