Strengths, Weaknesses, Opportunities and Threats of Manufactured Buildings

A Sustainable Built Environment National Research Centre (SBEnrc) Research Report

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1. Introduction

A focus on innovation

Manufactured housing practices date back nearly a century with the first housing construction production line being created in the United States in 1926,[1] followed by the UK post World War II,[2] and Japan in 1955.[3] More recently, in 2012, the output of the prefabricated building industry globally has been estimated to be at US$90.1 billion, with the largest regional market being Asia-Pacific valued at US$44.4 billion, followed by Europe valued at US $31.5 billion and North America valued at US$10.2 billion.[4] Despite the popularity and growth of manufactured housing globally, the uptake in Australia is still comparatively small at 3%[5] of the global market. However, the industry aspires to achieve a 10% growth in the residential sector by 2020.[6]

This report looks at the relative strengths and weaknesses of different types of manufactured housing and explores the barriers and challenges to the industry being further developed in Australia. The research investigates the current level of innovation in the manufactured building industry considering both the product and the process.

The findings in the report provide a SWOT analysis (Strength, Weakness, Opportunities and Threats) of manufactured buildings. The aim of this research is to present a balanced assessment of SWOT factors to inform consideration of increasing the uptake of manufactured buildings as a potential housing sustainability option (including economic, social and environmental outcomes) in Australia.

The SWOT analysis also considers the following:

1) Analysis of the strengths and weaknesses by looking at real life examples of successes and failures;
2) Provision of a gap analysis of metrics, which is required to fully understand the performance of the manufactured housing industry;
3) Evaluation of the perceptions of people in the construction industry about manufactured buildings, those both directly and indirectly involved in the construction industry;
4) Performance statistics for manufactured housing related to value-adding factors such as time, cost, quality and long-term sustainability benefits of manufactured building systems and;
5) Identification of practical solutions for stakeholders such that the industry can innovate and grow to its fullest potential.

In Australia, the idea of manufactured building is not new. The first set of portable iron clad homes constructed in the UK, were transported to Melbourne by ship in the 1850s however, the major leap in the area of prefabricated construction took place after World War II.[7] The current focus of the Australian market is on building elements such as roof trusses, window fittings, and prestressed concrete slabs.

When looking for ideas on how to inform the expansion of the manufactured building industry in Australia, one place to look could be the technological and innovative advances made by the

aerospace, shipbuilding, and automotive industries, where industrialised processes have improved the efficiency and quality of the product.[8] Another place could be the challenges faced by the manufactured building industries in Great Britain and Sweden in the 60s and 70s, where the focus was on mass production rather than on improving customer-orientation and process management (design, production and information sharing), resulting in poor uptake.[9] Finally, the industry could look at the substantial benefits available to customers and the market to effectively increase demand.

> *From the occupant's perspective, standardising the construction process can satisfy any number of definitions of value. For example, a balance of lower time, optimum cost and higher quality can be achieved with due attention given to the whole life cycle assessment.* ***The social acceptability of prefabrication and standardisation in relation to new housing*** [10]

In order for customers to realise this value, they may need to better understand the features of manufactured buildings, and what value they actually add. Hence, it will be important to adopt a 'consumer-oriented' approach that can demonstrate clear value for customers at the design phase in order to increase the uptake of manufactured buildings.

The industrialisation of the building sector

A wide array of parameters been used by different prefabricated companies/projects and these are analysed in this report to showcase their success and failure factors over conventional industries. Although the practices applied are different, a universal model of practices for manufactured buildings can be developed.

Key focus of this research

A key focus of this industry led research project for the Sustainable Built Environment National Research Centre (SBEnrc) is on investigating and compiling evidence relating to the performance of manufactured buildings. The intention is to inform those that are, or are looking to become active in the area of manufactured building. This will be complimented by an analysis of existing manufacturing methods and processes (such as the model shown in Figure A) and how these could be used for the expansion of the manufactured buildings sector in Australia.

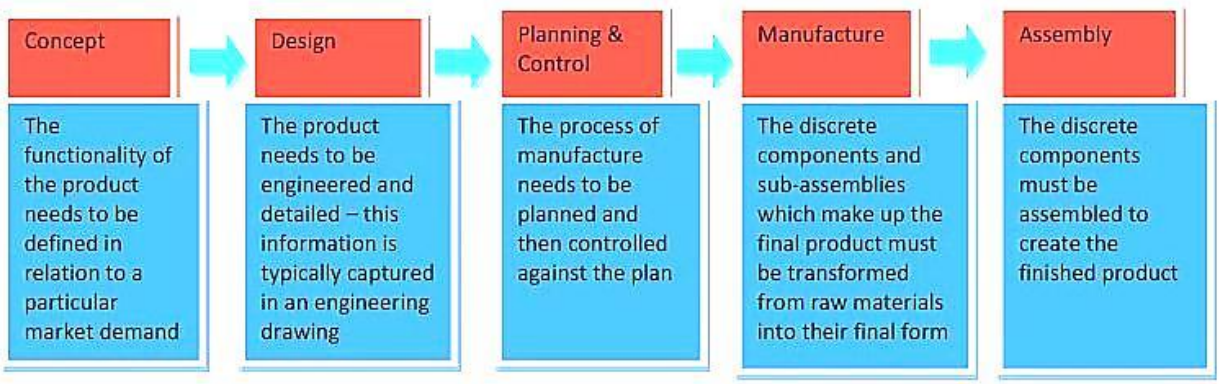


Figure A: The evolution of discrete assembly manufacturing[11]

If the construction industry wants to become more efficient and productive it will need to learn new processes. When considering the potential for processes such as those shown in Figure A, it becomes clear that a manufacturing approach to building construction can:

- *Harness economics of scale*[12] to achieve cost reductions with multiple buildings manufactured on a single site allowing benefits such as efficient inventory management, and reducing the defects, transportation costs, and time delays associated with onsite construction. Some examples of quantifiable benefits of manufactured buildings are as follows:

  - *Waste reduction* of 52% was achieved in private and public residential buildings in Hong Kong.[13]
  - *Construction time reduced* by 50-60% in the 'Little Hero Project' built by Unitised Building (Australia) when both on-site and off-site operations were carried out in parallel.[14]
  - *Facilitate tighter management control*[15] with streamlined communication between factory and onsite teams for process, product delivery, and management approach.
  - *Minimise on-site operation and duration*[16] with much of the construction taking place offsite, thus allowing the on-site duration, theft, and health and safety hazards to be substantially reduced for example:
    - a company using modular construction services in the UK, reduced its project costs by 11%[17] (calculated using cost-time distribution), and another project reduced its labour by 75%[18] more than a conventional project.
    - as shown in Figure B below, the risks of theft and vandalism on manufactured building sites are much lower because fewer materials have to be stored on-site, and after the delivery of module buildings they can be locked and secured.[19]

Figure B: Modular versus Stick-Built Construction: Which Delivers?[20]

- *Reduce construction waste* due to the fact that multiple buildings are constructed on the same site allowing waste materials from one house to be quickly used in the construction

of other houses. Furthermore, as manufacturing typically takes place indoors damage to building materials is reduced since they are not subjected to weathering.

- *Improve safety and workplace* conditions because workers are able to work indoors and avoid health and safety hazards, which generally take place on-site i.e. poor and extreme weather conditions.[21]

However, despite leadership from countries like Japan and the UK, the benefits of manufactured building have not yet been fully realised by the building sector in Australia. There are number of reasons why this is the case:[22]

Different Australian States have varying weather conditions (extremes of heat and cold) calling for a range of materials and processes to meet national needs:

1) Lack of a 'nationally-focused' and standardised training and professional development in the area of manufactured buildings system similar to the UK and Germany;
2) Perception that manufactured buildings are 'kit-homes' and not able to compete with traditional methods; and
3) A strong monopoly within the supply chain for conventional building methods.

While a number of barriers to entry and expansion exist in Australia, some progress has been made in understanding the opportunity presented. The UK Egan Report 1998 titled '*Rethinking Construction*'[23] underlines that offsite assembly is one of the key elements contributing to improvement in the construction of product and processes. Furthermore, the Australian report *'Construction 2020'* produced by the former CRC for Construction Innovation emphasised the use of off-site components to improve the state of the future construction environment.[24]

Although gains attributed to the wider scale use of off-site construction incorporating manufacturing practices are well documented, the systematic and holistic evaluation of the overall benefits and applicability of manufactured buildings practices on specific projects remain limited.[25]

Clarification of terminology

Due to manufactured building practices being developed in different parts of the world a diverse vernacular exists to describe the practice, illustrated in Table 1.

For the purpose of this research project we will use the terms 'Manufactured Building' or 'Building Manufacturing'. These terms have been selected as they encompass many of the other terms used, and can be applied to both residential and commercial buildings.

– Pre-Fabricated Buildings	– **Kit Homes**
– Offsite Production (OSP)[26]	– **Offsite Fabrication (OSF)[27]**
– Offsite Manufacturing (OSM)[28]	– **Offsite Construction (OSC)[29]**
– Preassembly and Prefabrication[30]	– **Industrialised Building System (IBS)[31]**

Table 1: Terminologies used for prefabrication in construction and building sector

Are manufactured buildings appropriate for Australia?

There are a number of justifications that merit further investigation of the potential of manufactured buildings in Australia these include:

- ***Housing Affordability*:** Manufactured buildings cost less than conventional buildings, which improves their affordability. As per the '*9th Annual Demographia International Housing Affordability Survey*' Australia had '30 severely unaffordable markets' based on the 'Median Multiple', which is the median house price divided by gross before tax annual median household income.[32] In Australia a long-term planning aimed to offer affordable housing catering low to middle income households still remains a big challenge. This is based on the fact that only 5% of the homes sold or built in the country in the year 2010-2011 were affordable for low income households[33] furthermore, in the year 2012 households on a national minimum wage paid 37% higher than in the year 2003 based on a median priced rental.[34]
- ***Carbon Intensity:*** *Th*e Australian residential and commercial building sectors are estimated to produce 23% of the country's greenhouse g*as emissions.*[35] *'In Australia, current housing construction practice is unsustainable in terms of the energy required for production of the materials used as well as required for the operation of the resultant dwellings*.'[36]
- ***Housing Shortage*:** The Australian housing market is facing a housing shortage despite a slow market growth, which calls for the delivery of a diverse range of housing. Manufactured buildings can provide cost savings that increase housing affordability, and as they are quality designed can lead to lower energy costs during operation.[37] In Australia the gap between demand and supply has reached a critical point. In 2011, there was an overall cumulative undersupply of 243,700 new homes, 225,000 families were waiting up to a decade on the social housing waiting list, and there was a shortage of 539,000 affordable rental properties available for low to moderate households.[38]
- ***Economic Impact:*** The growing level of housing supply gap is unhealthy for a prosperous economy like Australia, and this ever-increasing gap in supply has resulted in Australia being tagged as one of the world's most unaffordable housing markets.[39]

  Investigations relating to this have begun with the former CRC for Construction Innovation releasing a report in 2007 on the 'current state and future directions of offsite manufacture in Australia,'[40] which identified offsite manufacturing as a force that could underpin the improvement of the construction industry in Australia in terms of productivity, efficiency and sustainability performance. Furthermore, 'co-dependency on public acceptance, volume

production and distribution infrastructure',[41] have been identified as important factors defining the future success of manufactured housing in Australia.[42] However, a lack of consumer demand for new and alternative building methods act as a major stumbling block for adopting an innovative approach like a manufactured building system.[43] Therefore, this new report seeks to build upon existing investigations, and connect industry and government with leading research and practices in the area of manufactured buildings to inform considerations to increase the uptake of the method.

Manufactured building in Australia

In Australia an overview of different businesses comprising of either a manufacturer of manufactured housing products or a builder using those products is shown in Table 2 below. In line with the business types, 'the market penetration of the different business types was ranked as low (a developing industry), moderate (evidence of a significant number of well-established businesses) or high (dominant or prominent use).'[45]

Table 2: Overview of identified prefabricated housing businesses by business type[46]

Business Type	N	Moderate Penetration
Manufacturers/Builders Complete houses and finished modules	74	Moderate
Manufacturers SIPS panels Precast concrete panels Pods Other structural panels	 19 30 9 3	 Moderate Moderate Low Low
Builders Using SIPs Using precast concrete panels … …for detached housing …for multi-residential apartments …Using other structural panel systems	 25 11 Many 4	 Low Low High Low

As shown in Table 3 below, the major proportion of manufacturers and builders identified were from the eastern coast eastern cities such as Brisbane, Sydney and Melbourne, followed by small clusters in and around other capital cities like Perth, Adelaide, Hobart and Darwin.

Table 3: Prefabricated housing businesses by business type, by Australian State/Territory[47]

Business Type	N1	Qld	NSW	Vic	Tas	SA	NT	WA	ACT
Manufacturers/Builders Complete houses and finished modules	74	20	20	19	7	5	2	14	0
Manufacturers SIPS panels Precast concrete panels Pods	19 30 9	10 9 3	7 9 2	6 11 4	1 2 0	2 3 0	1 1 0	6 8 0	0 0 0
Builders Using SIPs Using precast concrete panels … …for detached housing …for multi-residential apartments …Using other structural panel systems	25 11 Many 4	6 0 - 0	4 7 - 1	5 2 - 1	1 0 - 0	2 0 - 0	1 0 - 0	6 2 - 1	1 0 - 0

Decreasing the Size of Prefabricated Components/Amount of Preassembly Increasing Degree of Onsite Construction Labour

Prefabricated Components ▶ **Processed Materials**

Refers to any single assembly fabricated in the factory, usually because it cannot be built onsite or can be used to assist construction speed or quality.

Figure 2.1.1.3 *IBM Traveling Pavilion by Renzo Piano:* This was a moving exhibition that was broken down into a series of prefabricated components that were designed with demountability and reassembly in mind (Dini 1984, 79).

Building elements fabricated offsite and shipped to the building site constitute the majority of the materials used in construction today, enabling larger spans, custom finishes, and the introduction of economies of scale to the bill of materials.

Figure 2.1.1.4 *Eames House by Charles and Ray Eames:* The Eames house was famously designed to be built from 'off-the-shelf' standardized materials as much as possible (Smith 2007, 23).

Modular Structures ▶ **Panelized Structures**

Components that are volumetric in shape and that form a completed part of a building (or a complete building in itself), and involves more than one trade typically with finished interior and exterior surfaces.

Figure 2.1.1.1 *Habitat '67 by Moshe Safdie:* Habitat is an assembly of prefabricated concrete modules (Safdie 1970, 23).

Components that are comprised of a series of prefabricated elements (window assemblies, door assemblies, wall panels) but do not enclose usable space themselves, typically forming the shell only of a building and require more onsite work than 3-dimensional components but will be cheaper to ship to the site in a compact form.

Figure 2.1.1.2 *Furniture House by Shigeru Ban:* Ban used panelized structures for the interior structural skeleton of the building (McQuaid 2003, 167).

Figure C: Sample classification of prefabricated systems[48]

2. SWOT analysis of building manufacturing

The initial analysis undertaken as part of the SBEnrc research project has focused on an assessment of the strengths, weaknesses, opportunities and threats in relation to manufactured buildings. The findings are shown below.

Strengths of building manufacturing

Cost reduction

- Construction and project costs can be considerably reduced, for example by reducing the need for materials (such as brick) and skills (such as bricklayers), especially as some States now have shortages in these areas, owing to: repurposing building components and sub-systems in a factory;[49] avoiding expensive weather and on-site related delays;[50] and reducing 1 to 2% extra costs for 'snagging' and 'call-backs'.[51] Labour costs are also dramatically reduced as higher resource efficiency is achieved with less manpower hours, as shown in Figure D.

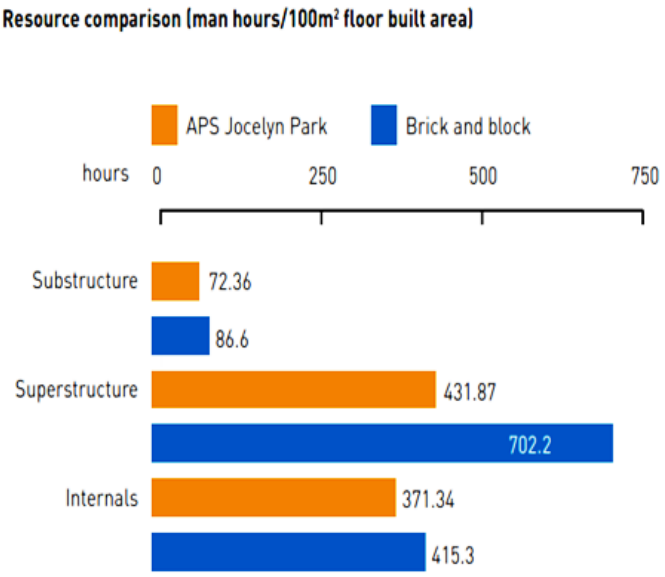


Figure D: Comparison of resource efficiency for Advanced Panel Systems (APS) against brick and mortar[52]

- As modular projects are replicable, design costs can be saved along with timesavings as both site works and building assembly within a factory are done simultaneously.[53]

  Manufactured style of construction as an alternative cost-effective building concept could be applied on mostly all types of buildings, including commercial and residential; however, particularly projects such as apartments, hotels, student hostels, classrooms, prisons and mining accommodations, in which replicable structures are used, seem to have greater cost benefits.

Time

- Construction time can be significantly reduced due to the central location of construction allowing for efficient project management and defect elimination, with examples such as: 50-60% reduction in overall construction time in the 'Little Hero' project completed by Unitised Building in Melbourne;[54] and defect reduction from 9.3% in traditional to 7.3% (defects per habitat) in manufactured residential buildings in Hong Kong, when inspections were carried out after the project completion.[55]

  The Chinese International Marine Containers (CIMC – Modular Building Systems) in Port Hedland, Western Australia delivered 96 single storey completed buildings within 11 weeks for the first leg of the project, including all of the enterprise project management activities; and subsequently in the second leg of the project they delivered a 248 double storey building within 20 weeks.[56]

  Project timelines can be minimised by using advanced computer programs like BIM (Building Information modelling), and state-of-the-art technology like digital fabrication offering greater emphasis to 'individual mass customisation'.[57]

Productivity

- Productivity is improved and construction processes are effectively managed through the application of: performance improvement practices such as Lean; linear assembly line techniques such as JIT (Just-In-Time); and robotics. In the 'Little Hero Project' by Unitised Building these tools helped to ensure predictability and consistency, and also to allow for close tolerances based on a grid design.[58]

  Better working conditions offered to both workforce and the overall industry in terms of job security and improved organisation learning help to improve the productivity of the project.[59]

Quality

- Longevity of products is much greater than conventional, with design life as much as 100 years, due to factors such as periodic quality inspections on a product's consistency and durability,[60] which is achieved in a controlled factory environment supported by precision-driven automated machines.[61]

  Quality is also enhanced as complex digital data exchange and storage are effectively handled with the help of modern ICT (Information and Communication Technology) tools at an early product development stage.

  BIM has been identified as a critical tool to improve the coordination and systematic working in a fast paced factory set-up, which requires multiple trades and processes working hand-in-hand.[63] A survey conducted by McGraw-Hill Construction, shows that 78% of the respondents who have used modular construction implement BIM on other projects; as compared to only 48% using BIM that have not used modular construction.[64]

Environmental performance (waste reduction, energy efficiency, land use)

- Construction waste is reduced, with examples ranging from 52% for a residential building project in Hong Kong,[65] to zero demolition waste produced due to precision related efficiencies allowing for reconfiguration and relocation from factory-based fabrication.[66]

  Traditional building processes produce a lot of waste representing nearly 20% of the raw material tonnages (considered 10% as a reasonable amount across all building types), in monetary terms this comes approximately to 3-5 % of the construction cost.[67]

- The energy efficiency of building designs can be optimised using processes including rapid prototyping, database technology, and parametric modelling, which also help to integrate renewable energy and building science technologies.[68]
- There are very limited studies done on the emission released at a site due to traffic movements; however, a study in the year 2011 at University of Virginia (as shown in Figure E below) based on comparison of both onsite and offsite operations demonstrated a net CO2 emissions reduction of around 20%. Housing density and Brownfield infill objectives can be more rapidly achieved while reducing urban sprawl.[69]

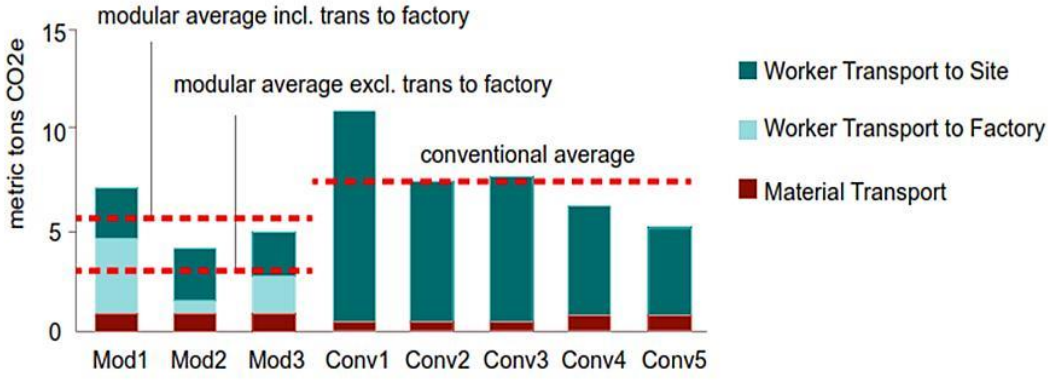


Figure E: Onsite-Offsite comparison of CO2 emissions due to transport.[70]

Similarly, another research work (as shown in Figure F below) demonstrated net CO2 emissions reduction due to energy use of around 30%.

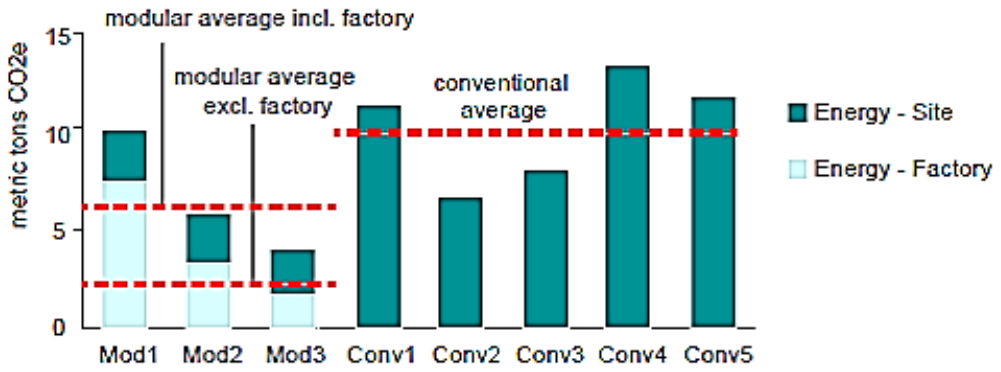


Figure F: Onsite-Offsite comparison of CO2 emissions due to energy use[71]

Case Study 1: The 'Little Hero' Project by Unitised Building in Victoria, Australia[72] achieved a variety of benefits using steel pods, which include:

- Smaller carbon footprint over the construction phase and complete life cycle of the project;[73]
- Designed to achieve passive cooling;
- Better recyclability of components and materials;
- Production of less on-site waste; and
- Improved tolerances through a tighter building envelope, improving heating and cooling performance.[74]

Case Study 2: Chinese International Marine Containers (CIMC – Modular Building Systems) were given a contract to deliver 96 single storey and 248 double storey manufactured buildings for BHP Billiton (BHPB) in Port Hedland, Western Australia.[75] Some of the features of the project include:

- **Better acoustic performance:** Although the site of the buildings is located close to major transport hubs and services such as Port Hedland Airport, highway and railway, the buildings still have extremely high standards of acoustic performance.
- **Improved cyclone strength:** The buildings were designed and fabricated to meet the highest cyclone categorisation Australian Cyclone Structural Standard (AS1170.2-2002), Region D, Category 1.
- ***Ready-to-use scope:*** The buildings had to be brought to use without any on-site time lags with all engineering, procurement, fabrication and fit-outs completed beforehand. After initial foundation and set-up work the buildings were fully ready to accommodate the transient workers of the mining industry.
- **Supply Chain Management (SCM):** Higher quality design outcomes are achievable, due to suppliers being involved in preliminary designs;[76] therefore, it gets easier to engage suppliers in the process earlier and avoid future onsite issues.

Transparency and stronger relationships between supply-chain participants can be established as management is located in the factory (as in the 'Little Hero' Project in Melbourne, Australia).[77]

Lower staff turnover, greater loyalty, reduced absenteeism and better job security can be offered to the workforce as reliance on subcontractor's work is reduced.[78]

A centralised management system enables process repetitiveness involving the single party suppliers that bypass decision-making bottlenecks present in on-site based construction.[79]

- **Health and safety:** Heights that the workers operate are reduced,[80] along with reduced exposure to cement and contaminated soil.[81] The 'Little Hero' building project ensured the highest standards of safety for workers by installing all faced work required for glazing, balconies and other associated jobs within the factory.[82]

With reference to the Figure G, the accident rates in manufacturing are 29% less for major injuries and 52% less for fatalities (calculated on the basis of latest 3 year averages). From this it gets clear, that if construction were to work similar to that of manufacturing because of its increasing up-take off-site processes, a significant decrease in injuries and fatalities could be prominent.[83]

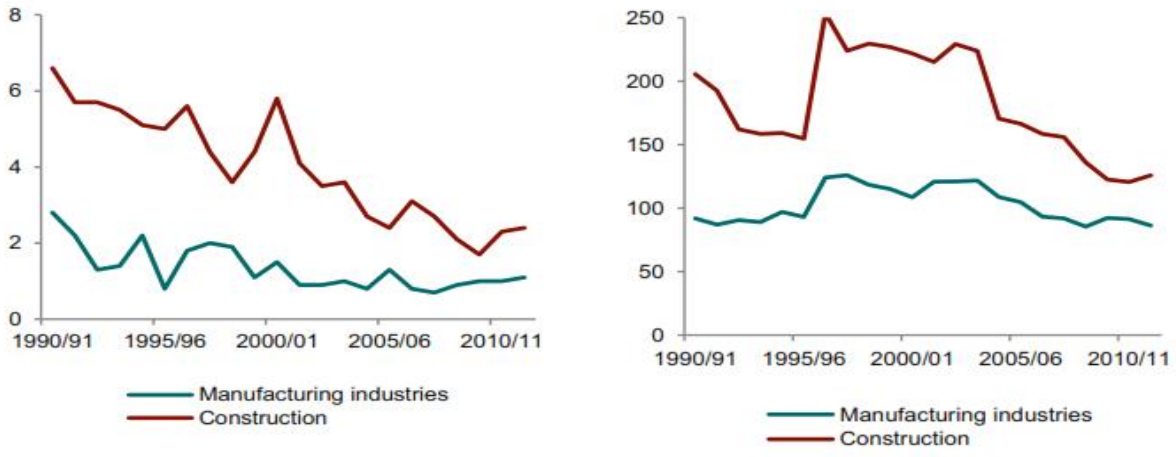


Figure G: Fatal Injury Rate (left graph) and Major Injury Rate (right graph) per 100,000 (employees and self-employed).[84]

3. Weaknesses of building manufacturing

Capacity building

- Greater market uptake of manufactured buildings is inhibited primarily because of insufficient experience in using the approach,[84] scarce quantified and hard research information,[85] and a lack of education and training programmes. [86]
- Lack of skilled labour in the manufactured building industry[87] is another prevalent issue, for example: fire crews may not be sufficiently trained to tackle fire issues associated with manufactured buildings;[88] and on-site based construction workers can be unskilled in operating automatic machines in a factory.
- The mainstream building industry and associated training and apprenticeship programmes do not currently focus on manufactured buildings;[89] therefore the pool of labour that has this skill set is small.
- The quantum of the manufactured buildings industry is not known, nor its potential size and growth rate, therefore little effort is given to expanding the skills in this domain.
- Information technology is not comprehensively utilised compared to other industries; the low level of IT (Information Technology) integration in Australian construction industry has made the barriers to entry significant, resulting in manufactured building products being seen as uneconomical and unviable.[90]

Perceptions about manufactured building systems

- Sometimes-spurious notions about 'high initial capital outlay, cranage and transport costs', extra pre-planning and coordination, and a requirement for a different set-up of payment terms and cash-flow arrangements mainly drive negative perceptions within the industry.[91]
- Inaccurate cost evaluations based on accounting for direct costs such as material, labour and transportation, and often ignoring other indirect cost-related factors such as site facilities, correction works, and crane use as well as potential savings from shorter construction times.[92]
- Preconceived views exist that the products are not fit for purpose, for example it is considered that higher quality products designed with high precision may not fit the imprecise onsite components.
- A strong consumer fascination to double-brick housing in Western Australia would discount the real benefits of economies of scale and other associated advantages of manufacturing in construction.
- Past quality issues in some projects have impacted the reputation of manufactured buildings. For example:
    - One manufacturer of precast components found that it was common to have water leakage at the joints between the walls with the post-installation method; although, silica was used to fill up the joints, deterioration was noticed after 10-15 years;

- Structural limitations such as durability, sound insulation, fire resistance and waste tightness surfaced in some projects; and
- Inefficient control over manufacturing processes made the concrete walls and floors too thick and overweight, resulting in lifting and joining problems.

Process and people

- Instances of unsuitable site conditions for the movement and transportation of manufactured building components. For example, the 'Little Hero' project had to have strict controls over traffic management (delivery before peak traffic, street enclosure and control of pedestrians) for on-site pod delivery to meet the project delivery deadlines.
- Pricing of the final product can increase, as fabrication facilities require overhead for maintenance, equipment and utilities, and also due to higher transport cost and logistics primarily due to module size and distance of site from the factory.
- Construction industries do not use efficient procurement methods like project partnering and strategic partnering alliance as they still heavily rely on traditional methods based on 'fixed price/lump-sum'. If manufactured buildings rely on traditional procurement methods then prospects of establishing long-term relationship between project partners might be affected by lack of trust and understanding.
- Financial decisions are the drivers behind critical decisions, with an understanding mainly based on conventional approaches and experience based decisions of key personnel, and less emphasis is given on 'transparent robust methods.'
- In one study of manufactured buildings in the City of Chongqing in China the following were some of the challenges faced:
  1) Lack of coordination between design, manufacture and erection;
  2) Lackof mutual working efforts between the design and research companies;
  3) Inefficient supply chain management in the construction industry; and
  4) Limited application of systemised building techniques.
- Flexibility, with regards to design modifications during late construction stages for manufactured buildings, is considered limited and not at par with onsite based construction. As shown in Figure H, efforts have to be focused on increasing the flexibility.

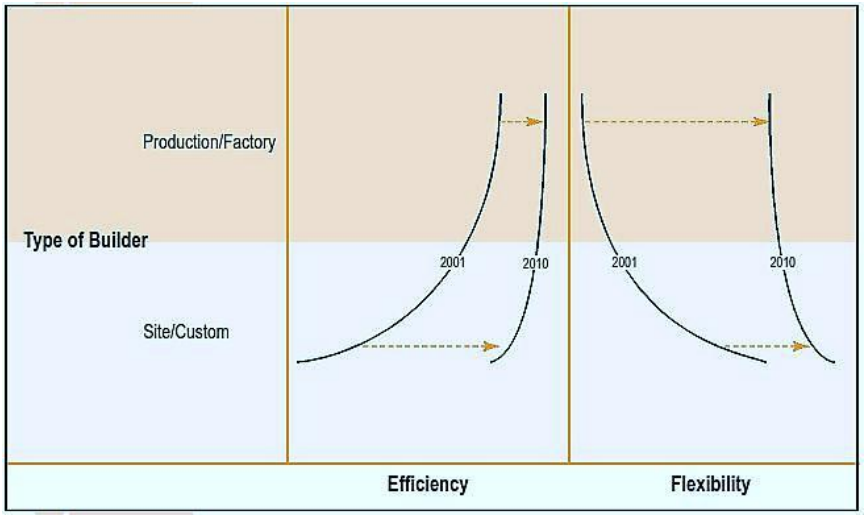


Figure H, Technology Roadmap: Whole house and Building Process Redesign[99]

With manufactured building practices, lack of upfront meticulous design can increase risks of construction bottlenecks and schedule delays, which subsequently might increase the cost of products. However, this can be effectively dealt with by developing full mock-ups, thus enabling the project team to have a higher degree of certainty associated with the design and construction of the final manufactured building products.

4. Opportunities of building manufacturing

Need for affordable housing

- The need for affordable housing provides an opportunity for manufactured buildings as they can rapidly deliver product to market at a lower cost than traditional options. This is a significant opportunity considering that in Australia there was a dramatic fall in affordability of just less than 60% over the 5 years from 2001 to 2006.[100]
- The Australian Greens recognise manufactured housing as a solution to deliver affordable homes to the masses within a period of 10 years. They have set a target (as shown in Table 4 below) to deliver more sustainable and more affordable manufactured housing within the next decade.[101]

Table 4: Australian Greens' National Affordable Housing Platform with manufactured housing targets[102]

	New homes per year	Total by 2024	Pre Fab target	Total pre fab by 2024
Homelessness	1000	7000	50%	3500
Social Housing	12,200	122,000	33%	40,260
NRAS	5000	50,000	33%	16,500
Student NRAS	2000	20,000	33%	6600
Convert to Rent	1500	15,000	33%	4950
		214,000		**71,810**

Job creation

- Training offered to the workforce to acquire transferable and new manufactured building industry skills[104] will provide employment opportunities to local communities,[105] and will also help the dysfunctional manufacturing sector to revive.[106]
- Manufactured building systems need to have a unique set of skills starting from the whole supply chain, research, design, manufacturing building components, through to fabrication and construction of final products.[107]

International competitiveness

- With appropriate policy support the manufactured buildings market could expand to provide international investment and export opportunities.[108] Such internationalisation helps to forge

partnership arrangements to inform and educate clients about newer possibilities of manufactured buildings.[109] For example, the federal government's housing affordability policy has created opportunities for local and international manufactured housing developers in Melbourne.[110]

Contribution to sustainability

- Sustainability goals can be achieved by developing affordable and environmental friendly mass-produced manufactured housing;[111] this can be helpful in demonstrating the 'resource-saving' strategies to improve awareness of the products (Japanese housing manufacturers);[112]
- In a nutshell, 'Sustainability involves the simultaneous pursuit of economic prosperity, environmental quality and social equity'.[113] Manufactured building systems have many aspects that clearly re-define triple bottom line benefits ranging from reduced waste because of factory-controlled operations through to reduced financial costs due to shorter onsite construction activities and programmes;[114] and
- More sustainable end products can be developed, according to Nicole Robertson of GRO Architects of United States, as digital technology is used in both design and fabrication.[115]

Capture first mover advantage

- The growing number of case studies and examples of manufactured building provides quantifiable data that can inform efforts to capture first mover advantage in this sector by providing strong evidence to clients and investors.[116] For example:
  - In one instance, the 'Misawa Homes Group' in Japan in 1995 demonstrated that manufactured homes were found to have 67% less air-leakage than conventional homes.[117]
  - In Japan housing manufacturers offer a 'ten-year warranty' along with 'post-purchase services', which included free regular inspections and check-ups to maintain the quality of product for long-term use.[118]
- In Australia, Unitised Building has achieved the appearance and aesthetics of a classic apartment building, rather than appearing as a transportable building with the building's facades integrating well with the surrounding buildings.[119]

Financing

- In Australia, Unitised Building[120] had the access to construction funding and project progress payments for manufactured building pods that were completed, but not installed; this presently stands as an exception in the construction industry, where contracts usually require projects to be completed to a certain stage on-site before releasing payments.[121]

- There is the potential for a streamlined financial approval process, given the example that a major Australian bank lent to a low carbon public housing project for Vic Urban at Coburg, owing to the successful track record of the 'Little Hero' project built by Unitised Building.

While financing a modular home is an exciting journey, it can be demanding and stressful if proper planning is not undertaken. Typically, there are eight determinant steps of financing manufactured homes, similar to that of stick-built homes, which are followed in the United States of America (Step 1 to Step 8).[122] Generally, the same steps are followed in other parts of the world, including Australia. These steps provide guidance to a manufactured home buyer to take informed decision and acquire finance for their untraditional homes from banks and financial institutions.

Step 1: Selection of mortgage providers having:

- Experience in manufactured homes;
- Close ties with manufacturers; and
- Loan types with better interest rates and acceptable financial stipulations.

Step 2: Pre-qualification estimate, which will enable to:

- Determine the buying power; and
- Organise the budget required for initial payments and other preliminary expenses.

Step 3: Mortgage Approval:

- A formal commitment letter is issued after the bank is satisfied about the mortgage prerequisites;
- The letter contains the amount sanctioned by the bank along with conditions and restrictions; and
- Borrower has to provide deed for building lot and blueprints of the modular home to the bank.

Step 4: Starting the formal application process:

- Check to cover the fees (application review, credit check and appraisal);
- Proposed contract for the home that is planned to be purchased;
- Borrower has to present details of any existing loan statements, pay slips from employer; and
- Initial down payment to be made by the borrower (it is desired to be in the range of 5-20% of the total cost).

Step 5: Disbursement Schedule:

- When and how much to pay to the general contractor (for subcontractor payments and building materials);
- When and how much to pay to the vendors (in absence of a general contractor); and
- Timely inspection to prove that the work has been completed satisfactorily.

Step 6: Mortgage Closing:

- Signing of the final loan documents and pay for the closing cost (which is from 4% to 7%) to cover lawyer fees, title fees and other costs.

Step 7: Building the house:

- Payments are made as building milestone is reached and verified;
- Borrower starts making scheduled payments to the bank for the first time; and
- Largest disbursement happens when the modules arrive on the site.

Step 8: Transferring from the Construction Loan to Permanent Mortgage:

- Home is appraised to ensure that the home value is right, all work has been completed and no liens have been placed by a vendor (signing a lien waiver from general contractor upon receiving the final payment is a proof); and
- Paying the transfer fees from construction loan to permanent mortgage.

Increase in natural disasters

- There is an opportunity to capitalise on the growing number and severity of natural hazards and disasters with the structural resistance compatible design aspects of manufactured buildings to turbulent geographical locations. A study conducted by the 'Foremost Insurance Company' has shown that on-site constructed homes are more than twice as likely to catch fire as compared to manufactured homes.[123] An example of a hazard resistance technology in Australia is shown in Figure I.

Figure I: A benchmarked display building resistant to hazards such as bushfires, earthquake and tsunamis, designed by Unibuild Technology. [124]

Growth in market for new building products

There is an opportunity for increased demand of lightweight and low-carbon intensive products such as engineered solid wood and cross-laminated timber panels,[125] along with lightweight but durable steel as building materials, because of their capability and physical properties to replace traditional materials.

Timber has been used for many generations in the building and construction industry, due to properties such as structural strength, design flexibility and ease of use[126], and for being

lightweight. Regardless of so many advantages offered by timber to the building and construction industry, susceptibility to termite attack is a common risk faced in many States across Australia. According to an Australian government study on 'Termite Risk Management' – out of 350 species of termites in Australia less than 8% cause economic damage to houses.[127] This is still a significant threat to the housing industry and therefore, it is worth considering the impacts of termites on the Cross Laminated Timbers (CLTs) used in the manufactured building industry. It is not just timber construction which is being attacked by termites, a study by CSIRO found that even houses constructed using concrete and steel virtually have the same risks of being attacked.[128]

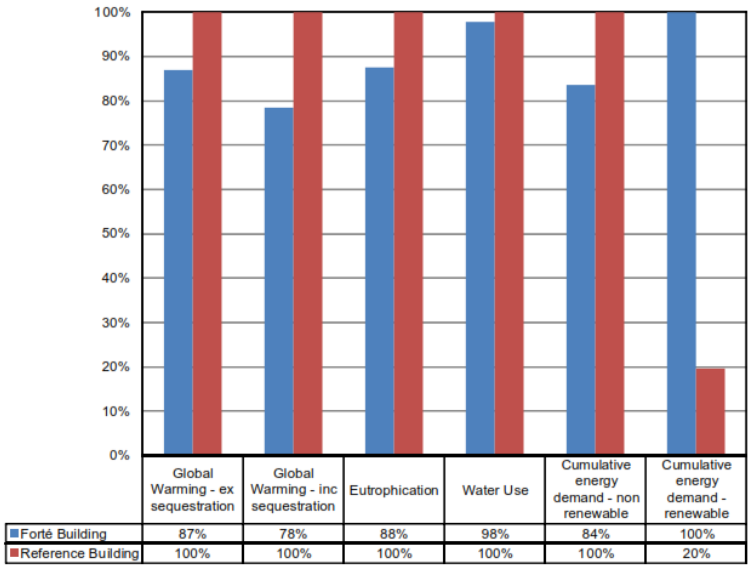
In Australia vulnerability to termites also depends on factors such as the climatic zone and the relative humidity of place where the building is being constructed. Most widely, AS3660.1 is used as a standard termite management toolkit in Australia,[129] it is compliant to BCA (Building Code of Australia) and provides different physical and chemical measures; however along with these set of measures to keep termites out, regular building inspections have to be carried out by termite management professionals.[130]

From above it is clear that preventing the termite attacks on the buildings is a significant financial investment, and therefore considering the use of termite resistant building materials plays an important role in curbing the economic losses. It is apparent that manufactured housing companies have started to shift their focus on using CLTs (Cross Laminated Timbers) and light-weight durable steel, as primary building materials because of their physical capability to put off termites in addition to many other long-term sustainability benefits.

Cross Laminated Timber (CLT) and Steel

CLT (Cross Laminated Timber) is basically an engineered building material that has significant benefits such as fire, acoustic and structural performance, material stability and construction efficiency over light wood frame techniques, and can endure the same pressure of prefabricated and reinforced concrete.[131] It is not only just used for small housing and building projects, but also in the construction of multi-storeyed buildings demanding greater structural stability and energy performance.

Although Cross Laminated Timber (CLT) has recently evolved and is being used as one of the main sources of building materials in Australia, it has predominantly been successful in the construction of multi-storeyed residential and commercial buildings in the European market, due to its exceptional sustainability features.[132] A testimony to this is the recently completed Forte project by Lend Lease in Melbourne, Australia. This project showcased that CLT over its entire life cycle, when compared to a building constructed using reinforced concrete (named reference building) offers a 22% lower carbon footprint as well as other sustainability gains[133] as shown in Figure J below.



	Global Warming - ex sequestration	Global Warming - inc sequestration	Eutrophication	Water Use	Cumulative energy demand - non renewable	Cumulative energy demand - renewable
Forté Building	87%	78%	88%	98%	84%	100%
Reference Building	100%	100%	100%	100%	100%	20%

Figure J: Relative impacts for the Forté building and Reference building, by category (Scaled to the highest impact for that specific category).[134]

Steel as Termite Deterrent: Nova Deko is a company, which specialises in modular homes. Heavy-duty steel frames that have substantial structural strength and ability to withstand extreme weather conditions are used in the manufacturing. As Nova Deko modules are steel framed and are elevated on steel piers, they act as termite resistant and therefore offer far more lifecycle than structural timber prone to termite attacks.[135]

5. Threats to building manufacturing

Negative attitudes

- The perception that manufactured building techniques[135] and products are cheap and have low quality, and are only used in remote locations with major emphasis on affordability.[136]
- Substantial initial investment can be required for obtaining certifications, registrations and approvals for manufactured building plants.[137]
- Time consuming planning approvals for some projects, for instance, the apartment project at Merri Creek location faced 90 objections from Darebin Council. [138]
- The sense of familiarity is greater than the desire for experimentation and innovation in the Australianhousing market.[139]

Finance

Difficulty in acquiring finance in Australia for manufactured building[140] and 'concerns over mortgage and insurance availability.'[141] For example, the first major scale apartment building project (Little Hero) in Australia could not secure financial support from any major national bank and had to get finance from an overseas financial institution, the Arab Bank.[142]

High initial start-up cost

The high initial investment to set-up a factory to produce a wide range of prefabricated modules and components for a manufactured residential building is one of the challenges resulting in the wider residential building sector being sceptical about making a shift from a traditional system of construction to a manufactured building system. However, return on investments can justify the upfront capital costs. Furthermore, for any new product to be successful in a market it has to be tested and satisfactory results need to be developed, this gets difficult as:[143]

- The economic benefits of manufactured building systems are difficult to be realised without a stable long-term market demand for the products over the period of amortised heavy financial investments, therefore to achieve payback there has to be continued sufficient demand for the product on one hand; and
- On the other hand, to have such demands, assurance of market with major scale housing policies supported by strong financial plans is needed.
- In another instance, a client of Unibuild in Canberra was refused full loan fund as the project was a manufactured building and considered to be not meeting the traditional entrenched progress payment structure of the bank.[144]

*Note: There are some companies in Australia that provide insurance to manufactured buildings, including MHIA, QBE and ARPRA. However, the premium is linked with the type of manufactured building. For example, if the house has got fixed footings/foundations then premiums would be low as compared to something that is mobile or transportable.

Competition, market trends and geographical location

- A strong presence of labour unions in the Australian market supporting the traditional construction industry presents a challenge to manufactured building.[145]
- Inclination towards specific products and structures by users and or clients (for example: a large fascination for double-brick housing in Western Australia).
- Increase in fuel prices would impact the overall cost of final product, as fuel is required to operate machineries and transport manufactured building products. [146]
- Undoubtedly, after the global financial crisis, the already competitive housing construction industry was highly impacted; although, there was no clear relationship of a negative effect it had on the manufactured building industry.[147] For example the plummeting housing market stuck by the worldwide financial downturn during 2007 and 2008 resulted in an increase in the uptake of manufactured housing in Japan, [148] furthermore in Germany a stable trend was noticed at 9% in spite of a dramatic variation in the total number of dwellings built.[149]
- Some other factors impacting greater uptake of manufactured buildings in the Australian construction industry include:
  - Transportation of large components due to reasons such as: 'mass of items', 'road widths', 'bridge load capacities' and 'transport curfews; and
  - 'Crane driver vulnerability in some states due to unionisation, severe weather, and hook time availability.'[150]

Reduced demand for traditional trades

In a lacklustre economy, mechanisation and use of automated systems according to many experts would destroy jobs.[151] The notion is not different when it comes to a building and construction community, as many think that manufactured building technologies would hit the job market hard. This would mean limited amount of work, rendering the major proportion of the skilled workforce unemployed. On one hand, a strong debate prevalent in the market is that greater potential of manufacturing processes would decrease the demand for traditional skills, and this may further result in either a 'multi-skilling' or 'de-skilling' situation.[152] It is anticipated, on the other hand, that the manufactured building model will rather create more jobs, as it will address the pivotal sustainable construction agendas on a much wider and global scale.[153] This will happen mainly because the system will help to achieve greater productivity outcomes by using efficient and standard inventory strategies to minimise the need for interoperability and transactional costs as a result of much reduced errors and accidents than conventional construction practices.

Undeniably, the introduction of manufacturing techniques and processes will have an impact on the construction workforce; this could be narrowed down to two areas:

1) Firstly, the lower level workforce such as traditional trade roles of professionals such as carpentry and plastering is not going to be changed, but the context in which they are applied will be diverse (including both on-site and off-site operations).

2) Secondly, more significant changes are expected to happen to the higher management staff as they have been operating in traditional 'silo-based' approaches, and therefore will be required to make a shift to skills and professional disciplines.[154]

The demand to learn both off-site and on-site principles will gradually increase, as manufactured building processes will require an increased integrative approach between design, engineering and manufacturing/construction disciplines (as shown in Figure K below). This will result in more training and education programmes to equip the workforce with transferable skills and will also attract youngsters to take up professions in the area of manufactured building.

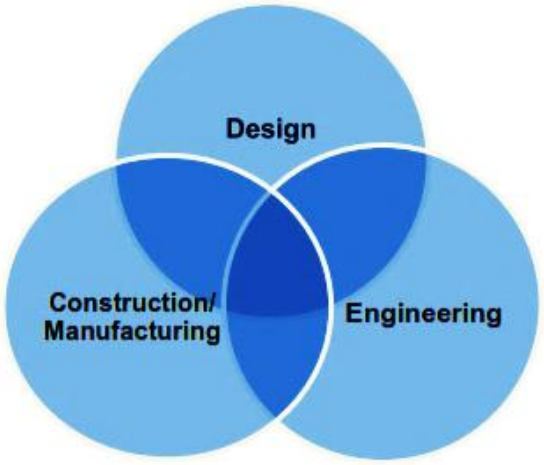


Figure K: Predicted-increasing integration between different disciplines.[155]

Not getting stuck at the compliance/permit stage.

Whether the manufacture of the modules is local or international they have to abide by the local building act. For example in Victoria, irrespective of modules being manufactured locally or internationally, the Domestic Building Contracts Act and Building Act are implied on the builder, into the design and construction contract for the rectification of defects of modules.[156]

However, there are some unclear areas when rectification of defects (electric or structural fault) is considered in the modules. To avoid any sort of disputes and stress the contract must clearly state the contractual arrangements below:

a) Specify the responsibility for interface items;

b) Set out a process for the determination of a fault;

c) Provide for the coordination and rectification of a fault; and

d) State the process for recovery of payment for the rectification of defects.[157]

In addition to the above, the following legal issues in manufactured construction in the contracts should also be addressed:

a) The transfer of title in the modules (on delivery, assembly, issue of occupancy certificate or rectification of defects);

b) The structure of milestone payments (e.g. upfront, on delivery to site or incorporation into the building and final rectification of defects; and

c) Where international manufacturers are used, the practicality of rectifying defects, enforcement of security, solvency, availability of professional indemnity insurance and the application of the United Nations *Convention on Contracts for the International Sale of Goods*.

By following the above guidelines any kind of discrepancies at the compliance/permit stage can be avoided.

Case Study: The Nova Deko homes are built with maximum thrust to quality and are fully compliant to the Australian Building Code. The windows and doors surpass the minimum standard requirements. For example Nova Deko windows and glass doors are toughened 5mm-thick double-glazed panels, which is more than the standard minimum requirement of 3mm for windows.[158]

6. Conclusion

This report sets out the potential for manufactured buildings to be both cheaper and lower in its environmental footprint than current methods of housing in Australia. In this way it is a true example of the new green economy and will substantially alter the present construction industry if implemented in significant numbers. The next phase of research is to see what are the best examples emerging of this new technology in Australia and what are the barriers to its expansion.

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