Investigating the Mainstreaming of Building Manufacture in Australia

A Sustainable Built Environment National Research Centre (SBEnrc)

Industry Report

in collaboration with the Cooperative Research Centre for Low Carbon Living

Sustainable Built Environment National Research Centre

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Preface

The Sustainable Built Environment National Research Centre (SBEnrc) and its predecessor, the Cooperative Research Centre (CRC) for Construction Innovation, is committed to making a strong contribution to innovation across the Australian built environment sector. We are dedicated to working collaboratively with industry and government to develop and disseminate practical research outcomes that improve industry practice and enhance our nation's competitiveness. We encourage you to draw on the results of this and our many other applied research projects to deliver tangible outcomes for your operations and look forward to opportunities to work together in the future.

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Synopsis

This report presents an investigation into the feasibility of the mainstreaming of building manufacture in Australia. The report highlights the associated strengths and opportunities, and provides guidance on how to overcome the weaknesses and respond to the threats.

The report outlines the potential to transition the automobile industry in Australia to enhance the skill set available in the buildings industry to deliver manufactured buildings. The report provides new evidence from Australian cases of manufactured buildings. The report calls for a greater focus on key barriers such as customer perception, barriers to finance, and verification of enhanced performance compared to traditional methods of construction.

Acknowledgments

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The research team is based at the Curtin University Sustainability Policy Institute and Griffith University.

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Harnessing Building Manufacturing to Strengthen the Building Industry in Australia

Introduction

In Australia, the prefabrication of buildings dates back to the early 1800's such as the first set of portable iron clad homes being shipped from the UK to Melbourne in the 1850's. Decades later, the aftermath of World War II[1] created conditions of abundant building materials and an urgent need for rapid rebuilding, leading a number of countries to turn to prefabrication of buildings. The first housing manufacturing plant was created in the United States in 1926[2], followed by the UK[3] and Japan in 1955[4].

In 2012, the economic output from the manufacture of buildings globally was estimated at just over US$90 billion, up from $60 billion in 2011. In 2014, the largest regional market was Asia-Pacific valued at US$44.4 billion, followed by Europe at US$31.5 billion and North America at US$10.2 billion.[5] The growing number of case studies and examples of manufacturing buildings provides quantifiable data that can inform efforts to capture the opportunities by providing strong evidence to developers, investors and homebuyers.

Despite the popularity and growth of building manufacture globally, and in particular the rapid growth in the Asia-Pacific region, the uptake in Australia is comparatively small representing some 3% of the domestic residential housing market (focused on offsite fabrication of roof trusses, window fittings and prestressed concrete slabs).

'Manufactured Buildings' is defined herein as 'the manufacture of entire buildings, or components of buildings, in centralised facilities using repeatable processes based on traditional building techniques to achieve parallel construction outcomes, prior to transportation for erection on site'.

In Scandinavian countries, the uptake is much greater with half of residential housing in Finland being manufactured and nearly three quarters in Sweden. There is much to learn from the experience of building manufacture in these countries to inform what is likely to be the industrialisation of the building industry globally in the coming decades.

For instance, Great Britain and Sweden during the 1960's and 70's had an initial focus on mass production rather than on meeting customer needs and ensuring an efficient and effective prefabrication process (design, production and information sharing), which resulted in poor uptake.[6]

There is great potential for the manufacture of buildings in Australia, for both the domestic and internation markets, that if harnessed could strengthen both the building and manufacturing sectors.

Indeed, it is likely that the current building construction model will prove to be insufficient to ensure the ongoing sustainability of the sector. The domestic building industry will face strong international competition in the near future, especially as the quality of imported prefabricated and manufactured building offerings are improving.

However, the mainstreaming of building manufacturing must be undertaken in such a way as to harness the existing pool of skills and trades, so as to allow workforce transitioning in a manner that strengthens industry.

Further, a number of challenges will need to be faced such as issues related to finance, insurance and warranty structures. For instance, until recently the Queensland Home Warranty Scheme that protects consumers and builders excluded '*offsite prefabrication in a factory of the whole of a building*'.[7]

The Business Case for Building Manufacture

Opportunities presented by building manufacture

Building manufacture allows for cost savings, faster delivery times and the reduction of a number of impacts associated with onsite building construction methods, as follows.

Cost Savings

The prefabrication of buildings stands to deliver a range of cost savings to developers, builders and owners. The potential for such savings opens up the opportunity for the greater provision of affordable and social housing, along with the provision of a higher level of quality and non-standard inclusions in buildings.

In particular, it would make 'sustainability' related inclusions that can deliver lower operating costs to occupants and owners more economically feasible at the construction stage (especially energy related inclusions).

The greatest cost benefits are achievable in projects where replicable structures are used, such as apartments, housing developments, hotels, student accommodation, classrooms, prisons and mining accommodation.

Direct costs savings are achieved from the faster delivery of buildings using prefabrication methods, along with reductions in construction waste (which can constitute some 40% of municipal solid waste).

Cost savings can also be gained from the higher level of reuse of materials in construction, reduced weather damage of materials, reduced damage caused from onsite handling in often restricted sites with multiple trades and the elimination of vandalism and site theft during construction.

Faster Delivery

The shift to the manufacture of buildings stands to significantly reduce construction times, along with reducing onsite delays often caused by waiting for materials delivery, difficulties in coordinating service providers and subcontractors, and inclement weather. Reducing construction times can lead to a range of benefits such as reducing the cost of fees from land taxes, equipment hire, fuel bills, employee insurances and workers compensation. The shift will also allow a greater volume of buildings to be delivered, as not only is the construction time shorter but it can also be carried out at the same time as site preparation (i.e. footings, retaining walls and landscaping). This is important as building manufacturing is likely to reduce the labour requirement of individual buildings, it will be important to compensate with a growth in building output.

Improved Work Place Conditions

The shift to the manufacture of buildings in dedicated facilities will provide a number of improvements to workplace conditions, including:

- protection from weather and other hazards for both workers and materials, along with the provision of appropriate lighting levels 24 hours a day,
- provision for use of central power tool facilities rather than the reliance on hand tools or portable power tools onsite, and
- greater ability to provide elevated platforms, mini cranes, roped harnesses and other safety equipment due to construction being undertaken in a fixed facility.

Lower Impact

The manufacture of buildings stands to reduce a number of impacts, such as:

- Economic Impacts: reducing the time homebuyers rent while their home is constructed.
- Social Impacts: significantly improving workplace occupational health and safety by bringing the majority of building construction indoors.
- Environmental Impacts: through reduced materials wastage, reduced materials transportation, greater inclusion of energy and water efficient elements, and the potential for greater use of recycled materials.

Supplier Flexibility

The shift to a centralised facility leads to a number of benefits, such as greater flexibility in supplier choice as materials can be stockpiled rather than being needed on demand at multiple sites across a city or region. The provision of a regular delivery location with dedicated loading bay facilities will reduce transportation costs of supplies and reduce time wastage through the assurance that there will be someone to sign for materials.[8]

Accelerating building manufacture in Australia

The manufacture of buildings has the potential to provide high quality and cost-effective houses, apartments, office blocks and a range of other building types, utilising the technologies, materials, design know-how and construction experience currently in both the building and manufacturing sectors.

This, together with the benefits pointed out previously, suggests that it is likely that a large part of building construction will shift from individual buildings constructed onsite to the aggregation of construction in dedicated facilities offsite to be transported for erection on site.

Manufacturing buildings need not completely replace conventional building approaches, but it stands to significantly increase its share in the market, particularly for multi-storey buildings. Despite the opportunities there are a number of challenges to overcome, both real and perceived, in order to mainstream building manufacture in Australia. For instance, there are lingering miss-perceptions around the costs involved in building manufacture and the ability to produce high-end homes and commercial buildings.

In the past, manufactured buildings have often been perceived to be only useful for site huts or temporary transportable rooms or offices which are common in Australian construction sites, mines and schools: however, the latest market offerings allow for high quality precision designed buildings to be produced.

As with a number of other advanced industries, such as renewable energy technology, the slow recognition of the value that can be created through the manufacture of buildings in Australia may lead to a missed opportunity with offshore providers dominating the nation's future building market.

In order to ensure its viability, the building sector in Australia needs to quickly develop the infrastructure for the construction of buildings in centralised facilities and their transport and erection on site.

This may involve a transition strategy that includes an initial push for the use of panelised onsite construction to build momentum in the manufacture and erection of prefabricated components and modules.

It is particularly important to develop the sector in a manner that takes advantage of the cost effectiveness of sourcing building modules offshore, otherwise such offerings will compete with domestic construction.

There are already cases of offshore building manufacturing plants that are importing Australian electrical and plumbing components to ensure that standards and codes are met when shipping to Australian customers.[10]

Hence, if Australia does not seize the opportunity of building manufacturing, foreign companies will certainly continue to bring them to market, which if not harnessed as part of the sector's overall development could lead to job losses across the building sector and its supply chain.

Along with such perceptions that need to be addressed, the shift to aggregating construction of buildings to dedicated facilities to be transported to site for erection presents a number of challenges to be addressed in order to progress the industry, as follows.

Perceptions of Quality

- Shift the perceptions of the industry and consumers around manufactured buildings

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being simply temporary reloadable structures to recognising them as high quality precision built buildings; this may be through demonstration buildings, education programs and qualifying the benefits to consumers.

Design Processes and Controls

- Ensure that design, construction,and erection processes harness the full potential of the building manufacturing model and allow a streamlined delivery.
- Consider the creation of new design codes to ensure inter-operability of standardised components and avoid re-invention of design practices by competing building companies which may hinder the overall industry. This may also assist the mobility of construction workers between manufactured building companies.
- Re-evaluate project management processes related to materials, goods and services supply. Such processes can capture benefits from constructing multiple buildings in one location, such as being able to stockpile building materials and cluster buildings for sub-contractors to work on multiple buildings on one site.

Institutional Structures

- Expand the coverage of building manufacture in codes and standards such as the National Construction Code and the Building Code of Australia from a focus on '*all onsite construction requirements*'[9] to include requirements for offsite construction, transportation and onsite erection.
- Standardise building transportation requirements and restrictions at a national level to allow for greater ease in interstate transportation of manufactured buildings or components.

Supply Chains

- Effectively engage with small businesses involved in building construction to support a shift from individual building contracts on various sites to a clustering of skills to deliver multiple building projects from a centralised factory-style facility.
- Develop efficient and effective building transportation and erection processes and equipment to minimise associated costs and maximise accessibility to various site conditions. This will involve the building industry working with trucking and crane companies to overcome existing limitations.

Financial Models

- Reduce completion risks such that the building is in the possession of the manufacturer up until delivery and may not be able to be easily completed should the manufacturer delay or even halt operations.
- Develop financing structures based on progress payments at different stages of onsite construction to support factory style construction prior to transportation to site of completed product for erection.

Defects and Insurances

- Establish clear and accountable processes for the rectification of defects, especially when sourcing building modules from overseas.
- Align insurance and warranty structures to support offsite construction and on-site erection.

Skills Development and Transitioning

- Provide capacity building to trades to adapt to building manufacture.
- Develop training courses and programs, along with incentive schemes to encourage upskilling.

Harnessing manufacturing strengths of declining industries

Much like Henry Ford revolutionising the automobile industry in 1908 by delivering the first affordable automobile to the middle class in America using a production line, there is a strong business case for industrialising the building sector in Australia.

Aggregating the construction of buildings into dedicated facilities to be quickly erected onsite, stands to create jobs, cut costs and position the sector to both compete with, and benefit from, offshore building manufacturing.

Early movers in this space have demonstrated the viability of manufacturing buildings in Australia, hinting at the potential for the transition from the previous onsite construction dominated building model to a building prefabrication model, potentially learning from the aerospace, shipbuilding and automotive industries.[11] Such a transition provides the potential for much needed employment options for workers within these declining industries.[12]

Expanding the capability of the building sector to undertake the manufacturing of buildings will require the harnessing of skill sets from manufacturing, in particular those developed in auto-manufacturing,[13] and hence Henry Ford's legacy lives on into a new sector.

This is great news for the Australian economy as given that Ford, Holden and Toyota, have signalled that they will stop Australian domestic car making by 2017, there is a great potential to retrofit factory facilities and provide work transitioning of staff into the building manufacturing operations.

This will create jobs and bring in valuable skills needed to enhance the building industry's current knowledge of building construction.

New skills needed by the building sector to deliver manufactured buildings will include design for manufacture, transportation and erection in modules, the procurement and management of central stores of materials to service a production line, and a re-evaluation of construction techniques to maximise the time saving benefits of modular construction.

Harnessing the knowhow and technology from other sectors such as the automotive sector will be crucial in Australia, capturing the opportunities associated with manufacturing buildings, especially in light of the rapid growth in building manufacture in the Asia-Pacific region. Even though it may not be able to compete with labour costs for similar operations in neighbouring countries there are advantages to offering a domestic supply, such as:[14]

- reduced transportation time and costs,
- easier commissioning and defect rectification, and
- greater level of certainty around post purchase support.

There is also value in sourcing building modules and/or components offshore to then fit out and/or erect using Australian industries, hence capturing the benefits of both options.

Assessment of Building Manufacture

Summary of Key Findings

The following presents the findings of a desktop analysis to present a balanced assessment of the strengths, weaknesses, opportunities and threats (SWOT) associated with manufacturing buildings. It is intended that these findings will inform consideration of increasing the uptake of manufactured buildings as a potential building sustainability option (including economic, social and environmental outcomes) in Australia.[15]

Table 1: SWOT Matrix of Building Manufacturing[16]

Strengths What strengths can we build upon?	**Weakness** What weakness do we need to remove?
– *Cost reduction* – *Time* – *Productivity* – *Quality* – *Environmental performance (Waste Reduction, Energy Efficiency, Land Use)* – *Supply Chain Management* – *Safety*	– *Capacity building* – *Perceptions about Manufactured Building Systems* – *Process and People*
Opportunities What opportunities can we utilise?	**Threats** What threats do we need to be aware of?
– *Need for affordable housing* – *Job Creation* – *International competitiveness* – *Contribution to sustainability* – *Capture first mover advantage* – *Financing* – *Increase in natural disasters* – *Growth in market for new building products*	– *Negative attitudes* – *Finance* – *Competition, market trends and geographical location* – *Reduced demand for traditional trades* – *Not getting stuck at the compliance/permit stage*

In order to gain insight into the actions that might be taken based on the findings of the SWOT analysis, a process for considering the relative importance of each finding was designed by the research team, with this element led by Griffith University, and the Project Steering Group were invited to indicate the importance of each element to their business, department, or organisation, as presented in Figure 1.

The greatest strengths of manufactured buildings were considered to be 'quality' and 'cost reduction'. The greatest weakness was considered to be the perceptions of manufactured buildings. The findings also suggest that the greatest opportunities are 'the need for affordable housing', 'contribution to sustainability' and 'job creation'; with finance considered to be the main threat.[17]

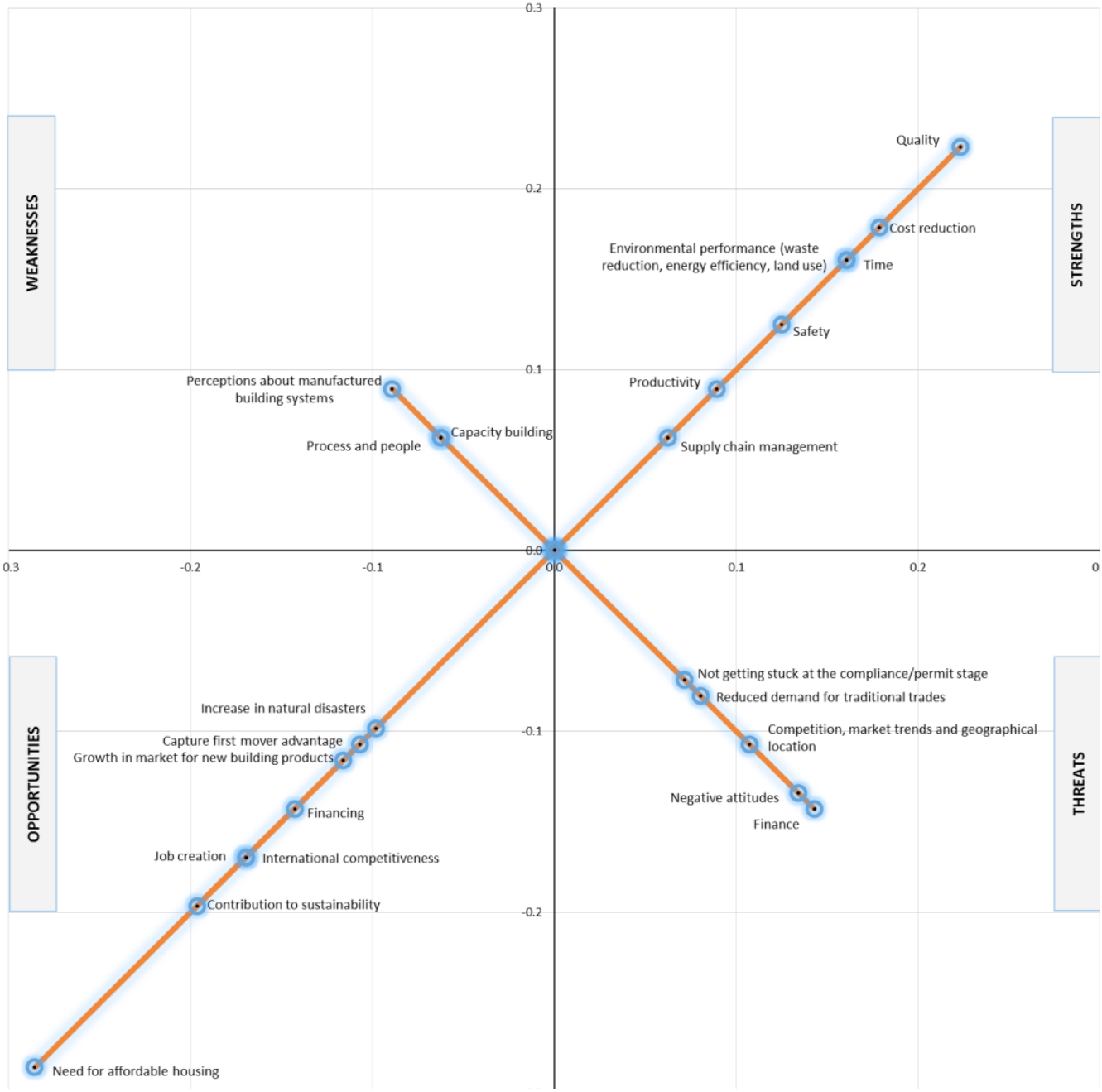

Figure 1: Relative perceived importance of strengths, weaknesses, opportunities and threats associated with building manufacture in Australia.

Performance Assessment Case Study

The Adara Apartments (Stella B17)

Introduction

The following summarises the key findings of a study led by Jemma Green (pictured below) that compared offsite (manufactured) and onsite construction of an apartment building in Cockburn Central, Perth. The Adara Apartments (Stella B17) development, a collaboration with the Western Australian Department of Housing and built by Australian builders Hickory Pty Ltd, consists of 77 apartments. The apartment complex was built in 11 months using offsite construction methods that included 96 prefabricated modules, with non-modular elements including the ground floor and two building cores.

As part of the research to develop the case study the actual offsite construction method was compared to a theoretical onsite construction method based on the use of a concrete precast wall structure with concrete slabs and brick walls. As part of the study, the cost comparison found that the offsite construction method delivered in the order of 10-12% cost savings.[18]

In their Australian-based modular building factory, Hickory uses steel framed modules, transporting them by truck and or by ship – both in this case. These modules are completely finished inside, including furnishings, plumbing and electrical wiring, and are glazed with complete external facades.

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Comparison of Construction Time

A comparison between the actual construction time for the offsite construction method used in the Stella B17 apartments and the anticipated onsite construction time found that the actual construction time was just under half the anticipated onsite timeframe, some 11 months compared to 2 years. This is due in large part to the ability for offsite construction to run site development and foundations in parallel with the building construction, along with the modular approach resulting in less site restoration activities, as shown in Figure 2.

Figure 2: Comparison of onsite and offsite construction schedules[19]

Comparison of Waste Generation

According to research commissioned by the Australian Government '19 *million tonnes of construction and demolition waste was generated in Australia in 2008-09*' with some 45% going to landfill and the rest recovered and recycled.[20] Given the value of construction material such as steel, concrete and aggregate, this presents a significant cost saving for the construction industry. Early studies have estimated that offsite construction of buildings can deliver as much as 70% less waste compared to onsite construction.[21]

The potential for significant reduction in construction waste is due to a range of factors, such as the ability to stockpile materials for use on multiple buildings and the near elimination of theft and vandalism along with weather damage to materials.

Furthermore, the centralised facility allows for materials to be processed at the facility, such as the steel frames used in the modules being cut and roll-formed to exact requirements in the factory, with only 10% of the steel being unused and recycled.[22]

The comparison of waste generation between onsite and offsite construction options for the B17 Stella apartment complex was undertaken on the modular part of the building (i.e. floors 1-7). Onsite construction is estimated to result in some 10% of the volume of materials being wasted on average.[23] According to the assessment of the B17 Stella it is estimated that offsite construction resulted in some 4.6% of the volume of materials being wasted, hence a reduction of 54% compared to average levels in onsite construction.

Comparison of Greenhouse Gas Emissions

An analysis of greenhouse gas emissions from both onsite and offsite building construction was undertaken (shown in Figure 3) using 'eTool', a free access Australian web-based software tool designed to evaluate the Life Cycle Assessment (LCA) of buildings compliant to ISO14040 2006, ISO14044 2006, BS EN 15978 2011 standards.

The analysis consisted of calculating the greenhouse gas emissions associated with assembly, finishings, floors, foundations, roof, walls, modular bathrooms, transport of materials and transport of modules.

- Assembly: In the case of onsite construction this take account of the energy consumed on site by cranes, concrete pumps, elevated work platforms, excavators, pile driver, loaders and other plant, along with power tools. In the case of offsite construction this takes into account the energy consumed in the factory, the fuel use by the crane to assemble the building on site, the consumption of energy to build foundations and to transfer all concrete elements of the building such as slabs, core walls (elevator and staircase) and stairways.
- Finishings: This takes account of all finishes, both internal and external, including plasterboard, cladding, floor coverings, tiling, doors, fixtures, balustrades, etc. as appropriate for each construction method.
- Floors: This takes account of flooring materials such as steel, plywood and insulation.
- Foundations: This takes into account the cement used in the foundations and structural elements as appropriate to each construction method.
- Roof: In the case of onsite construction this takes into account the roofing materials, plasterboard, mortar and painting for ceilings. In the case of offsite construction this takes into account the steel components of the structure, insulation and roofing sheets.
- Walls: This takes into account material used in walls, windows, insulation and doors, such as glass, cement, and brick as associated with each construction method.
- Modular bathrooms: The greenhouse gas emissions have been calculated on the offsite construction option as the bathrooms are created as a module and this takes into account all components and materials.

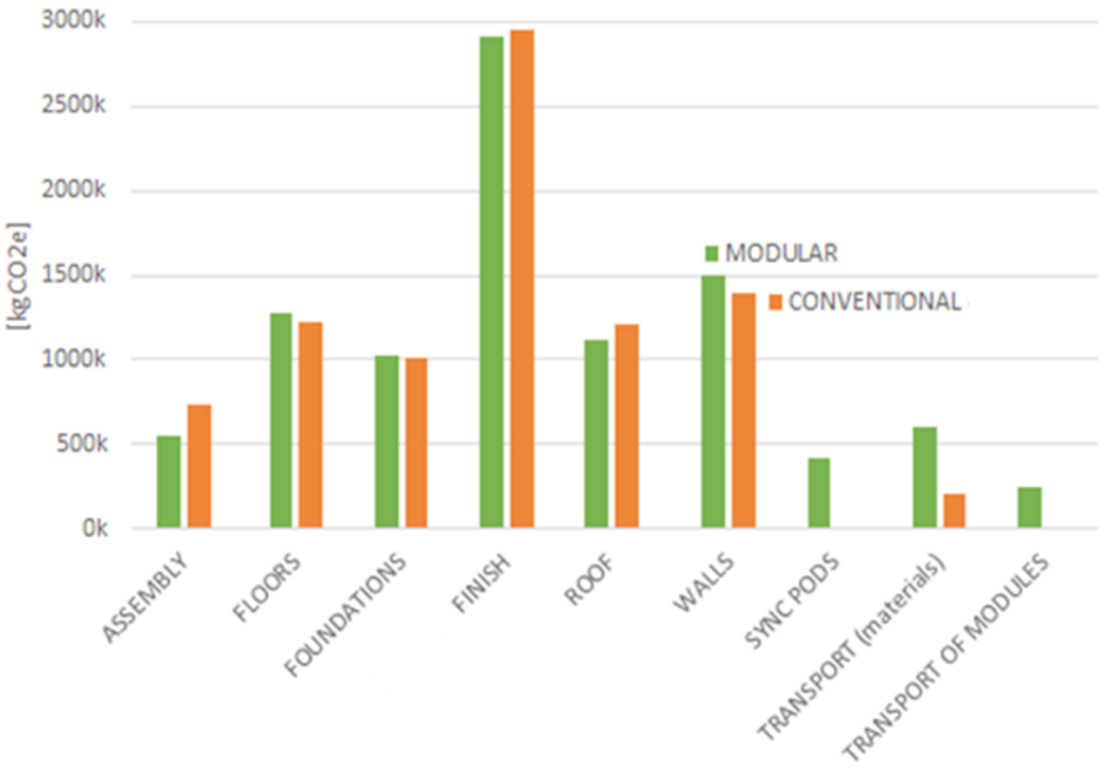

Figure 3: Comparison of Greenhouse Gas Emissions associated with onsite and offsite construction of the B17 Stella Apartment Complex, Cockburn Central, Perth.[24]

- Transport of Materials: In the case of on-site construction, this takes into account the transportation of materials to site, with the majority of materials sourced locally if not nationally. In the case of offsite construction, this includes steel transported from China and tiles transported from Italy to the building manufacturing facility.
- Transport of Building Modules: This takes into account the shipping of the 96 building modules from Melbourne to Fremantle,and the trucking to site.

As can be seen in Figure 3, there is a negligible difference in the overall construction related greenhouse gas emissions of onsite and offsite construction in this case, some 2.3% less emissions in onsite construction, largely due to the transportation related emissions.

However, as the industry grows, the ability to source materials locally and undertake offsite construction closer to building sites will reduce these emissions.

A similar assessment of the embodied energy associated with each option was undertaken and the results show 4.4% less embodied energy in onsite construction due in part to the 744 tonnes of steel frame used in the offsite construction method.

Further Research

If Australia does not seize the opportunity of building manufacturing, foreign companies will certainly continue to bring it to the market, which if not harnessed as part of the sector's overall development could lead to job losses across the building sector and its supply chain.

A key area for further research will be to significantly shift perceptions of the industry and consumers around manufactured buildings from being simply temporary relocatable structures to recognising them as high quality precision built buildings. Further research is need to investigate how hidden economic potential and affordability can be unlocked in the Australian building sector through a focus on building manufacture.

It is imperative that the building sector clearly understands the opportunities related to shifting from the current onsite construction model to an aggregated offsite construction model that can deliver cost savings, greater productivity and the creation of new skilled jobs.

There is a need to provide capacity building to trades to adapt to building prefabrication, this may involve both the development of training courses and programs along with incentive schemes to encourage upskilling.

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SBEnrc Overview

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. Established on 1 January 2010, the SBEnrc is a key research broker between industry, government and research organisations for the built environment industry.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the environmental, social and economic sustainability areas in programs respectively titled Greening the Built Environment; Developing Innovation and Safety Cultures; and Driving Productivity through Procurement.

Among the SBEnrc's objectives is to collaborate across organisational, state and national boundaries to develop a strong and enduring network of built environment research stakeholders and to build value-adding collaborative industry research teams.

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