Australia's Smart Building Revolution:

A Prefabrication Industry Roadmap 2023-2033

BUILDING THE FUTURE WE WANT

prefabAUS

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Introduction and Foreword from partners

On behalf of PrefabAUS, I am delighted to present Building The Future We Want, our Smart Building Industry Roadmap to Australia's engineering and construction sector, the manufacturing sector, our leaders in government (federal, state and local), to the industry's workforce and relevant unions, and to partners present and future from the education, training and research institutions.

The leadership, active support and collaboration of all these groups and institutions will be the indispensable underpinning for the ultimate success of this strategy.

But additionally, Building the Future We Want is addressed, most critically of all, to the Australian community, which is demanding solutions to some of our greatest problems: affordability and meeting the housing needs of all, moving to a low carbon economy and low carbon living, creating inclusive communities geared to an ageing population, and urgently diversifying our industrial base.

This Roadmap can deliver aggregate annual benefits of at least $9 billion to the Australian economy after a decade, owed mainly to cost reductions and improved productivity, but with additional likely productivity gains and further qualitative benefits to so many facets of Australia's economy and society.

For reasons given here, Australia is primed for take-off in Smart Building. But we will not get the needed uplift without strategy and leadership.

Prefabrication or offsite construction becomes today's Smart Building when it takes on comprehensively digital technologies and associated business models into all links or phases of the value chain: from design and planning, to inputs and intermediate processes, procurement and supply chain organisation, production and manufacturing, assembly, through-life support and systems and, end-market demand drivers.

Regardless of much excellence, Australia's prefabrication sector today is fragmented, mostly applying conventional construction methods away from the construction site, but yet to embrace the transformative potential of Industry 4.0 to every link of the Smart Building value chain.

This Roadmap is about accelerating Australia's development from prefabrication to Smart Building. At the same time, conventional builders can benefit from selective adoption of prefabrication facets, from digital technologies, to use of prefabricated parts, components and modules.

In developing this Roadmap prefabAUS and its partners held industry workshops in Adelaide, Melbourne, Sydney and Brisbane, with participants from almost all areas of the prefabrication value chain: architects, planners, builders, developers, manufacturers, and government agencies.

We received their feedback about such issues as: current industry capability and strengths and weaknesses; the industry's image in the marketplace; the priority actions and policies required; and the sector's levels of maturity, especially in uptake of digital technologies and Industry 4.0 and new business models.

The numerous descriptors of prefabrication are varied and confusing to say the least, so engagement on this subject was of interest to prefabAUS. The consensus was that the term Modern Methods of Construction currently best describes the industry, which leverages off terminology widely used in the UK. Going forward simplifying the descriptor to just Smart Building was the agreed better way of acknowledging how the industry is evolving.

In addition to the industry workshops, we conducted a review of literature from Australia and international sources, which took in lessons

and experiences from the public and private sectors, as well as key policies in play. We called upon specialist knowledge from within prefabAUS and its affiliated organisations and members, as well as expertise from participating universities. Many industry participants completed an Industry 4.0 diagnostic – futuremap® – to assess their digital readiness.

The Roadmap also builds on important prior work by prefabAUS and the Prefab Innovation Hub, supported by the Advanced Manufacturing Growth Centre (AMGC), covering issues and impediments for the prefabrication sector associated with access to capital, regulatory and standards regimes that are not fit for purpose, promoting critical technologies such as Design for Manufacture and Assembly (DfMA), and the Prefabrication Innovation Hub initiative.

I thank our partners in delivering the workshops and this Roadmap: the (AMGC), the Swinburne University of Technology, and the Building 4.0 CRC.

My thanks also to Ben Kehoe, whose ideas were a constant provocation to go further, and to Lance Worrall, who took on the research and analysis for much of the Roadmap, together with contributing to the strategic directions proposed here.

Some will ask why Building the Future We Want appears at a time of high rates of building and construction business insolvency, and a housing affordability crisis deeper than ever before? Is this the time for major change?

This is precisely the time for a comprehensive strategy to deliver higher construction sector productivity through prefabrication and Smart Building, and through the strong partnerships and collaborations of all those whose support is critical to our mission's success.

I look forward to working with you to build the future we want.

Damien Crough
Co-founder & Executive Chairman
PrefabAUS

Executive Summary and recommendations

Australia has everything to gain from rapid adoption of prefabrication and Smart Building.

Australia can reap an economy-wide annual benefit of $9 billion from 2033 through cost savings associated with Smart Building [1]. This is only one of the prizes to be won from Smart Building.

Smart Building opportunities are coming Australia's way. This prefabrication roadmap has been developed to help Australia make the most of those opportunities and to realise the accompanying benefits. Opportunities translate into benefits through the application of strategy, policies and programs, at the level of the individual business, the broader prefabrication sector and supply chain, and governments – national, state and local.

This Roadmap comprehensively outlines the prefabrication opportunity and its multifaceted benefits. It surveys the sector's key challenges, and how the key drivers can be harnessed and shaped toward its future growth. It proposes common directions for the industry's development that can be achieved if – and only if – it is supported through strong partnerships and leadership.

For individual businesses, as well as for the whole construction sector, prefabrication – the bringing together of construction with manufacturing, and Industry 4.0 with new business models – offers the prospect for new products, greater production efficiency, higher productivity, reduced waste and higher utilisation, shorter construction times, new business models, and better margins.

For the Australian economy, prefabrication is an opportunity to lock into a new source of industrial growth - a whole new value adding industry for the nation, which needs to rebalance its economy toward once again making things, away from excessive reliance on simple resource extraction.

For Australian society, prefabrication can help address challenges like housing affordability, population ageing, climate resilience and adaptation, and carbon reduction through greater energy efficiency and better design.

To capture these gains, we must do many things – from project coordination to build scale, to better diffusion of digital technologies throughout all links in the Smart Building value chain, to changing business models, to better appropriate standards and regulation, to building the workforce of the future, to better links with the investment community, to ensuring a productive ecosystem for the uptake of digital technologies and new ways of doing business, and so on.

Australia lags many other advanced countries in adoption of industrialised offsite construction. But other lagging nations are working hard to catch up, while leaders continue to grow in sophistication. Australia can learn from international experience of what works.

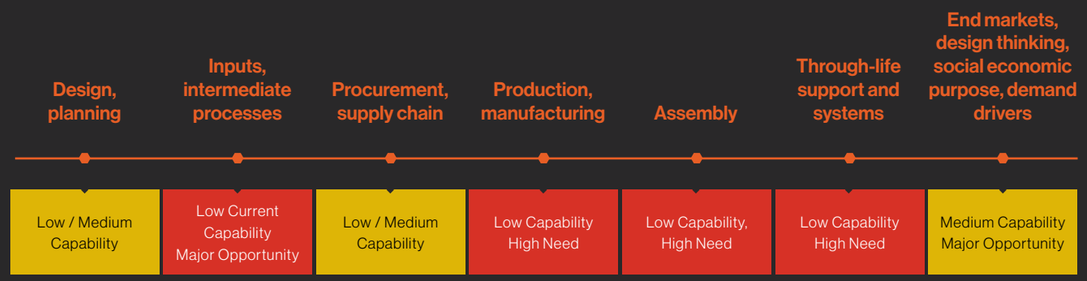
Despite, or rather because of, Australia's lagging take-up of prefabrication, it is actually at the forefront of international comparisons of what will drive rapid future growth of the sector. Faced with an acute shortage of housing alongside construction labour shortages, Australia has very high growth potential for Smart Building and prefabrication.

Australia's Smart Building value chain is disjointed - a mixed picture of reasonable capabilities alongside low ones needing urgent and concerted attention. The following assessments of capability along each stage of the value chain represent the consensus of opinion of participants in our industry workshops.

1 See Attachment 1 for detail on this conservative estimate.

Today, Australia's prefabrication sector is associated with, firstly, production offsite mostly using onsite processes and yet to embrace the full potential of digital technologies and, secondly, with cost-sensitive and basic products in the marketplace. It is not yet Smart Building.

AUSTRALIA AND THE SMART BUILDING VALUE CHAIN – SUMMARY



Recommendations

These recommendations and actions address how we go from basic prefabrication to Smart Building at scale.

1. Recognise the Importance of Smart Building in Government Industrial Policies

Australia lacks comprehensive policies to support the Smart Building revolution. But there are significant recent policy changes in favour of the nation's reindustrialisation, with implications for prefabrication and Smart Building.

Australia has a range of important initiatives supporting prefabrication and Smart Building, from state governments to university-based research bodies, aimed at developing future industry directions. But they do not constitute a national policy.

Nationally there is new recognition of the imperative of Australian reindustrialisation, principally through the National Reconstruction Fund (NRF), which has various touchpoints to prefabrication, and growing recognition too of the prefabrication sector's potential not only as a source of new industrial growth, but also as an aid in addressing a range of society wide challenges. The target to build 1.2 million new homes under the National Housing Accord (NHA) also presents opportunities to apply industrial methods and solutions at scale.

Elevate recognition of prefabrication and Smart Building in policy and programs by:

- Embedding Smart Building goals in existing national initiatives, especially the NRF and the NHA 1.2 million new homes initiative.
- Recognising explicitly prefabrication and Smart Building as a policy and program focus for a national integrated industrial policy approach and mission.
- Maximising coordination and forward planning between Commonwealth, state and local governments, the whole industry (developers, financiers, designers, manufacturers, assemblers, etc.), and trade unions, to build scale and set directions favourable to the development of prefabrication and Smart Building.
- Commencing development of industry performance baselines and metrics (cost and time savings over conventional, superior climate performance, etc.) to provide evidence and support for the society-wide changes urgently needed.
- Commencing identification of 10 exemplar Smart Building Flagships that will become demonstrators of the benefits of prefabrication.
- Creating a national mission for Smart Building, including explicit recognition of its connections to larger societal objectives of reindustrialisation, decarbonisation, and affordability and social inclusion.

Impact and Benefits

- High impact. Critical to unlocking the full range of Smart Building benefits, including $9 billion in annual returns to Australia's economy.

Key Players

- Governments, industry, superannuation funds, financial institutions, developers, trade unions.

2. Build scale: Apply strategic public procurement principles

A successful strategy leverages demand side drivers to build scale by applying strategic public procurement principles to selected large scale projects. These include building 1.2 million new homes, relevant projects attracting public support under the NRF, school and hospital builds, infrastructure for hosted major events (such as the Olympic Games), infrastructure development associated with the future defence expansion, and so on.

Strategic procurement should use large scale purchasing to set future directions and shape the market, as well as stimulate innovation and the creation of new products, processes and technologies, geared to resource efficiency, through-life energy efficiency, lower carbon footprint, and inclusive affordable housing.

Strategic public procurement would mandate or target (as appropriate) a specified quantity, quality and character of Smart Building projects, together with setting of outcome- and performance-based targets, such as a certain proportion of 3D bathroom pods, or use of responsible steel, or through-life energy efficiency.

It would maximise coordination and dovetailing of Commonwealth, State and where appropriate, Local government, projects of significant scale and size, as well as large private sector projects in receipt of significant public financial support.

In so doing, it would build project scale and visibility and capacity for forward planning, with a portfolio approach, providing industry with prospective information on the totality of actual and possible major projects on a 3-, 5- and 10-year rolling basis.

Commence development of major coordinated public procurement strategy to build Smart Building scale, with:

- Maximum coordination and dovetailing of Commonwealth, State and Local government projects of significant scale and size, as well as large private sector projects in receipt of public financial support
- A portfolio approach, where possible providing industry with prospective information on the totality of actual and possible major projects on a 3-, 5- and 10-year rolling basis, to build project scale, visibility and capacity for forward planning by industry
- A 'Presumption in favour of prefabrication' in selected projects
- A focus on sectors and projects meeting critical needs and providing exemplars and flagships demonstrating Smart Building performance and benefits
- Targets or, as appropriate mandates, in designated major projects (e.g., 1.2 million new homes, Olympic Games works, other) such as minimum level of Smart Building, use of low carbon materials, etc.
- Application of other strategic procurement principles including:
  - Assessing procurement decisions on whole of life costs and lifecycle value rather than price on completion
  - Assessing bids on their use of digital technologies in both production and in through-life operation of the project or building(s)
  - Assessing bids for their innovative content, in production and construction, through-life operation, and in solving site-specific or general challenges such as inclusive communities and low carbon living
  - High use of standardised quality componentry or, especially in the early stages, the development of standardised quality componentry for a given project that could be applied to subsequent projects
  - Using Early Contractor Involvement (ECI) to foster collaboration and align all links of the value chain, and to maximise opportunities for iterative solutions and innovations
  - Preparedness to break down large work packages into smaller ones to help develop, and provide opportunities to, a competent array of tier 2 and tier 3 suppliers.
- Training programs in public sector advanced procurement.
- Active advanced public procurement shaping the market, resulting in standardised components and systems corresponding to a kit of parts and standardised systems for the full suite of government infrastructure assets [2].

This would commence with targeted projects such as the Housing Australia Future Fund (HAFF) aspirational goal to build 1.2 million new homes, progressively becoming a comprehensive system applied to the full portfolio of major projects.

Impact and Benefits

- High impact. Critical to unlocking the full range of Smart Building benefits, including $9 billion returns to Australia's economy. Creates scale as well as new institutional processes as the basis of a virtuous cycle of Smart Building growth and development.

Key Players

- Governments, industry, superannuation funds, retail financial institutions, developers.

3. Position Smart Building within the NHA (1.2 million new homes) and other major projects

The NHA includes an aspirational target of 1.2 million new, well-located homes over the five years from 2024. The HAFF and its National Housing Infrastructure Facility (NHIF) will provide financing to affordable well-located housing projects, with high energy efficiency ratings. Other forthcoming major projects, such as construction for the Olympic Games, provide opportunity to grow the sector.

Housing has the highest potential to grow Australian Smart building rapidly. A focus on housing will build Smart Building capacity and capability applicable to all prefabrication subsectors. The housing focus allows greater realisation of prefabrication benefits earlier: higher productivity, affordability, low carbon living, and inclusive and ageing-friendly communities.

Recognising the strong fit of prefabrication and Smart Building with the scale and requirements of the NHA, HAFF and NHIF, together with their bringing together of national, state and local governments, investors, planners and standards authorities, and investors and superannuation funds:

- Set a target for prefabrication and the Smart Building share of the NHA target such that by its final year (2030) prefabrication and Smart Building account for at least 50 percent of the build for 2030.
- Use the NHA process, involving constructors, standards and accreditation bodies, planners, lending institutions and superannuation funds, to push through current impediments with model arrangements that prove their efficacy and value over time.
- Work to identify prospective supply chain capability requirements in advance to address gaps and weaknesses through industrial programs and policies.

To further build scale as the foundation for a Smart Building sector, identify other major projects for large scale application of prefabrication, and set prefabrication targets for them:

- Australian prefabrication supplies 50 percent of the build under the $2 billion package announced at the cancellation of the Melbourne Commonwealth Games, being the continuation of the promised new and upgraded sporting infrastructure projects, and the Regional Housing Fund to deliver more than 1300 new homes across the State's regions, including social and affordable housing.
- The 2032 Brisbane Olympics build achieves an 80 percent target for Australian prefabricated content in building and infrastructure.
- DFAT mandates use of Australian prefab solutions for the replacement of the Pacific

2 Office of Projects Victoria (Treasury and Finance), Offsite Construction Industry Analysis. Digital Build program 2021.

Islands assets as well as critical consular and diplomatic facilities.

- Recognising the security advantages of offsite construction, Australian prefabrication supplies the majority of the construction requirements of the Australian Defence Forces throughout the decade.

Impact and Benefits

- High impact. Critical to building scale to reap and to demonstrate benefits of Smart Building and develop broader understanding and acceptance of the advantages of Smart Building.

Key Players

- Governments, industry.

4. Embed Design for Manufacture and Assembly (DfMA) in projects

DfMA is critical to delivering large scale projects and an integrated, capable value chain, to mass customisation and shifting the image of the industry toward higher quality, amenity and performance. DfMA is critical to realisation of prefabrication benefits of higher productivity, significantly reduced cost and construction times, reduced waste and defect-free production, and delivery of items at fixed prices.

To play this integrative role, capabilities at the **design**, **planning** link (link 1) need to be augmented, while awareness of DfMA benefits and requirements must be disseminated along the whole value chain. DfMA brings standardisation and optimisation to prefabrication, reducing the number of parts and the costs of production. But DfMA is not a mandatory requirement often even in large projects.

Building Information Modelling (BIM) is widely used and can be the point of entry to larger deployment of DfMA, provided interfaces between them can be improved.

Recognising the essential integrative role of the developer in setting Smart Building project parameters and locking in key decisions at the frontend, enact the recommendations of the report 'Adoption of Design for Manufacture Assembly in Prefab Construction' [3], including:

- Devising a DfMA demonstration and education program targeted to businesses in the **design**, **planning** stage of Smart Building.
- Ensuring the program helps lift the common understanding – and application - of Smart Building and DfMA practices of all industry players, from financiers to regulators to planners to engineers and architects to manufacturers to developers and end customers.
- Establishing benchmarks for use of DfMA and leverage that increasing use to establish baselines on costs, time, wastage, climate friendliness, and greater circularity.
- Increasingly mandating DfMA for prequalification in major projects.
- Increasingly using DfMA to reduce waste, also to provide digital assurance of the provenance and nature of all materials and inputs used, and of their through-life environmental and climate performance and embed Circular Economy principles into Australia's Smart Building sector.
- Developing handbooks, guidelines, data and benchmarks to communicate DfMA requirements and benefits across the industry.
- Working to improve interfaces between existing BIM and newer DfMA systems.

An advanced program for embedding DfMA at the **design**, **planning** (link 1) and the **procurement**, **supply chain** (link 3) stages would complement the effort to build scale through advanced procurement demand forces. Both in turn support improvement and the building of capacity in the **production**, **manufacturing** (link 4), **assembly** (link 5) and **through-life support and systems** (link 6) stages of the value chain.

Impact and Benefits

- High impact. Critical to the value chain integration required for scale, and for the progressively rising demand over the decade, and high continued demand thereafter.

Key Players

- Governments, industry, education and training.

5. Improve access to capital: Finance

To help overcome structural barriers to the financing of Smart Building, we need dialogue and processes that give lenders confidence to invest, including development of new mortgage products and structures that reduce the risk of noncompletion and advance alternatives to the traditional progress payments system.

One model is the UK Build Offsite Property Assurance Scheme (BOPAS) which assists the flow of investment funds by providing an audit and accreditation regime for prefabrication company creditworthiness, product conformity and quality, and assurance of 60-year durability [4].

The $10 billion HAFF and the 1.2 million new homes initiative should be leveraged to achieve model arrangements for financing of Smart Building that will become embedded and serve the sector's long-term growth. This would provide a framework for assessing prefabrication company creditworthiness, product conformity and quality, and development of an online registry to showcase technologies, products, manufacturers and developers.

Support the aims of the prefabAUS reports 'Financing Innovation for Prefab Construction in Australia' and 'Regulatory barriers associated with prefabricated and modular construction' [5] regarding financing by:

- Leveraging the HAFF and 1.2 million new homes initiative to achieve model arrangements for financing of Smart Building that will become embedded and serve the sector's long-term growth.

Impact and Benefits

- High impact. Utilises scale and demand drivers to embed new practices and relationships favourable to Smart Building.

Key Players

- Governments, industry, superannuation funds, retail financial institutions, developers.

6. Build consistent nationwide standards and better regulation

The current regulatory framework is unfavourable to building the scale required for Smart Building. Yet regulation and standards can set positive directions and frameworks for industry growth. Regulation and standards should reinforce the image and reality of Smart Building as a preferred option for quality, through-life performance and environmental characteristics. The current regulatory framework discourages the scale required for Smart Building, inhibits flows of investment capital to large-scale projects, and inhibits realisation of Smart Building benefits.

Enact recommendations of 'Regulatory barriers associated with prefabricated and modular construction' [6] to:

- Change planning system requirements in the National Construction Code (NCC), the Building Code of Australia (BCA), and state and territory regulations to standardise definitions of prefabrication.

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3 PrefabAUS (October 2022), Adoption of Design for Manufacturing Assembly in Prefab Construction. Project Funding Agent: AMGC

4 PrefabAUS, Financing Innovation for Prefab Construction in Australia. Final Report, 16/06/22. Funded by AMGC; Partners: University of Melbourne and PrefabAUS.

5 Ibid, and HIA, AMGC, Swinburne University of Technology, 'Regulatory barriers associated with prefabricated and modular construction', Final Report, October 2022.

6 Ibid.

- Modernise building and construction regulations to support use and approval of prefabrication through a set of clear standards for prefabricated construction and products, with associated testing and certification regimes for manufacture and construction.
- Define roles and responsibilities along the value chain including addressing barriers associated with contracts, progress payments, licensing, inspections and insurance.
- Use regulation positively to achieve uplift and improve the industry's image.

Additionally, use the HAFF with its mandate to increase the supply of affordable and social housing (1.2 million new homes in the half decade from 2024) to leverage demand for prefabricated housing and accelerate development of consistent new regulations, standards, testing and certification.

Impact and Benefits

- High impact. Helps build scale and overcome fragmentation.

Key Players

- Governments, industry, financiers, developers.

7. Create an Industry 4.0 dedicated sectoral program focussed on production and manufacturing, assembly and, through-life support and systems

We must build these (currently weak but critical) links within the Smart Building value chain. Often lacking scale and capability, Small and Medium Enterprises (SMEs) are all the more reluctant to invest in digital technologies and associated workforce skills that would open up business opportunities. The adoption of digital technologies in association with new business models is critical for SMEs.

Devise a national limited-term program to:

- Accelerate digital adoption for Smart Building and strengthen **production**, **manufacturing**, **assembly** and **through-life support and systems** (links 4, 5 and 6 of the Smart Building Value Chain) to be delivered through the network of future factories recommended below ('Build the ecosystem') and in the Prefab Innovation Hub: Feasibility Study [7].

The program would use the futuremap® digital diagnostic tool to provide rapid orientation for participating businesses and help tailor the most productive pathways for each business.

Impact and Benefits

- Medium impact rising to high impact over the decade. Builds production capabilities indispensable to the Smart Building value chain, and upon which the strategy's success depends.

Key Players

- Governments, industry, trade unions, education and trainings, future factories.

8. Promote Business Model Innovation for the accelerated development of Smart Building

Business Model Innovation is a critical component of the transformation of the worldwide manufacturing and construction. Building on the potential of digital technologies, new business models emerge that bundle buildings with services [8].

Business Model Innovation is the way in which an enterprise creates and captures value by innovating in two or more of: products, processes, marketing, or firm organisation. Its value

7 AMGC (ND) Prefab Innovation Hub: Feasibility Study. Submission to the Department of Industry, Science, Energy and Resources.

8 Evolution of large-scale Industrialisation and Service – Innovation in Japanese Prefabrication Industry, Journal of Construction Innovation: Information, Process, Management, Volume 12Issue 2, Emerald Group Publishing Limited 2012.

proposition is capturing additional value and competitive advantage – a composite form of innovation at the intersection of these four areas. Superior organisation and innovative business models are harder for competitors to imitate than a discrete product or service.

Effective Business Model Innovation helps lock in customers for the longer term by bundling services of a long-term nature with products – 'servitisation' – and expands the role of new digital technologies from production to new products. In so doing, it creates new sources of business revenue.

Key examples are use of digital technologies to monitor the performance of the building from the perspective of an ageing community, and the climate performance of the building.

Integrate Business Model Innovation into the entire program for Smart Building development by:

- Linking digital adoption sometimes motivated by the prospect of production and efficiency gains only, to changes in business models that enable extension of markets and business revenues, through the development of product-service models (or servitisation) over time.
- Ensuring Business Model Innovation content in the dedicated Industry 4.0 sectoral program, as well as the business advisory and industry development programs delivered through the Prefabrication Innovation Hub ecosystem.
- Ensuring that large scale public procurement concerned with value for money and taking account of lifecycle costs and performance of buildings (not just their production and construction costs), adopts a product-service model where appropriate.

Impact and Benefits

- High impact. Helps to maximise benefits from digital adoption and Smart Building, and returns to society in lifecycle costs and performance of buildings (climate, inclusiveness, etc).

Key Players

- Governments, industry, financiers, developers, education and training, future factories, trade unions.

9. Build the future workforce

Australia's (predominantly conventional) construction sector will be challenged by even larger skills shortages and demographic pressure over the next half decade, with further adverse implications for affordability.

The resumption of immigration and population growth creates additional construction demand against constrained supply. At the same time, nearly 8 percent of the construction workforce exits the industry each year. Almost half a million new construction workers will be needed in the five years to November 2026. About half of these will be technicians and skilled trades [9].

Productivity and attraction and retention must be central to a robust workforce strategy, incorporating the growth of Smart Building and its distinct skills requirements.

Recognising that the future workforce will be the backbone of Australia's 21st Century Smart Building industry, we must lead the change. A more multiskilled workforce using a mix of construction skills and others related to manufacturing processes and digital technologies. Some traditionally separate trades will shade into each other at the margins, with a multiskilled production and assembly workforce undertaking certain tasks that were previously only able to be performed by the designated trade.

9 Master Builders' Association (April 2023), Future-Proofing Construction: A Workforce Blueprint.

Initiate processes and negotiations for a future workforce that will:

- Create opportunities for secure, rewarding career paths and progression.
- Initiate cooperative dialogue and negotiations between unions, industry and training providers, towards a workforce development framework for Smart Building and prefabrication.
- Promote a new trade certificate for prefabrication including digital skills, aimed at enhancing the role of workers and trade skills, not replacing them.
- Collocate TAFEs with future factories and other bodies comprising the Prefabrication Innovation Hub.
- Investigate group apprenticeship arrangements to build scale for the new apprenticeships.
- Promote a schools-based program providing an early pathway into TAFE and Smart Building careers.
- Examine appropriate opportunities for greater credit transfer and recognition of prior learning.

Impact and Benefits

- Medium impact rising to high over the decade. Critical to meeting the demands of a growing, scale-based Smart Building sector and to building a positive industry ecosystem.

Key Players

- Governments, industry, trade unions, education and training.

10. Build the ecosystem: Industry awareness, market information and Smart Building industry clusters

The required accelerated development necessitates a knowledge-intensive ecosystem able to supply services critical to that development, including applied research, technology demonstration and prototyping facilities, information on industry trends, markets and emerging product and service opportunities, workforce development issues, new business models, and so on.

Additionally, businesses operating within a positive ecosystem, including industry clusters, outperform enterprises that compete on their own. Industry clusters provide a framework for regional and nationwide industry collaboration around common needs and challenges, the better to meet competition from offshore. They balance inherent competitive tendencies with incentives to collaborate to build strong long-term competitive advantage and smart specialisation. Knowledge is shared and common directions agreed. Clusters find points of focus and problem-solving for effective collaboration and are supported by positive ecosystems and networks of future factories.

Enact recommendations of Prefab Innovation Hub: Feasibility Study[10] to:

- Establish a Smart Building network of business and industry development service providers from existing future factories to form a national Prefab Innovation Hub.
  - Each future factory would deliver a combination of general Smart Building services while also playing to key specialisations to develop an agile and expert national system.
  - Each future factory would be encouraged to collocate with relevant TAFE facilities to maximise integration with workforce development, and to make use of entry-level diagnostic tools such as futuremap®.
- Promote industry clusters as focal points for the accelerated development of the Smart Building sector, including:
- Convening an annual Smart Building Industry Forum under the auspice of prefabAUS to progress industry development, report industry baselines and developments against the targets and recommendations of this Roadmap, and its 3-, 5- and 10-year milestones.
- Establishing baselines and data on Smart Building businesses for annual review and as means of measuring qualitative industry development and quantitative industry growth. Developing frameworks and criteria for prequalification, registration and accreditation of businesses as Smart Builders, taking account of such existing frameworks as the UK's (BOPAS).
- Providing handbooks and guidelines for companies developing as Smart Building businesses.

Impact and Benefits

- Medium impact rising to high over the decade. The Prefabrication Hub would provide a vital durable, recognised framework for accelerated learning and capability development, while industry clusters help overcome industry fragmentation and establish baselines and frameworks essential to the strategy.

Key Players

- Industry, Governments, trade unions, education and training, future factories.

11. Create Flagships, Baselines and Benchmarks

Demonstrator projects help build quantifiable value propositions for Australia's Smart Building revolution, shifting decisions in favour of through-life value rather than simply cost. At the same time, these can change the return on investment (ROI) equations for major procurers, especially governments, thereby accelerating the desirable transformation.

The confidence to invest, the desire to purchase, the ability of governments to take decisions to set directions (and achieve an acceptable return on investment), all depend on demonstrated advantages of Smart Building over conventional. That requires demonstration projects providing baselines and benchmarks related to defined targets of a strategy.

For the public sector especially, the ability to use common metrics, baselines and benchmarks to make comparisons is critical to making credible decisions based on performance and through-life affordability.

Leverage data and baselines, and utilise flagship projects and targets and benchmarks to provide objective information in favour of the Smart Building revolution by:

- Designating 10 flagship Smart Building projects (inclusive of the NHA 1.2 million new homes target) as national demonstration projects
- Determining current baselines and performance goals against the targets enunciated in this Roadmap, including:
  - A 20 percent cost advantage over conventional
  - A home construction time advantage of 12 weeks over 12 months for a conventional build
  - A 50-80 percent reduction in waste (resource efficiency)
  - A 50-80 percent reduction in embodied carbon
  - Through-life carbon and energy benefits including 10-star energy rating.

10 AMGC (ND) Prefab Innovation Hub: Feasibility Study. Submission to the Department of Industry, Science, Energy and Resources.

Impact and Benefits

Medium impact rising to high impact over the decade. Concretely demonstrating Smart Building advantages against consistent baselines and benchmarks provides the bedrock for growing confidence of governments, the industry, wider business and the public.

Key Players

- Governments, industry, education and training, future factories.

12. Shift the image: from prefabrication to Smart Building

The combined changes wrought by the above recommendations and actions will achieve a broadly based enhanced perception of offsite construction: from prefabrication to Smart Building. Currently prefabrication is associated with firstly, production offsite mostly using onsite processes and yet to embrace the full potential of digital technologies and, secondly, with cost-sensitive and basic products in the marketplace.

As trends make themselves felt over time, and as the industry repositions, large scale procurement and individual consumers will demand that prefabrication become Smart Building. This means demand not only for affordability, but also for lower embodied carbon and higher ongoing energy efficiency, and communities that are inclusive of all and are ageing-appropriate.

This signifies a changing customer profile and a reorientation toward a quality market midpoint, rather than the low end.

The industry and governments should accelerate the required change by:

- Supporting and promoting exemplar projects to demonstrate Smart Building benefits and advantages – 10 flagships.
- As confidence and trust builds between developers, regulators, finance and investor bodies, and across the value chain, considering regulation and standards that institutionalise competitive advantage for prefabrication and Smart Building, and the use of regulation and certification regimes that operate as positive market shapers, such as:
  - Guaranteed climate performance standards (10-star energy rating)
  - A locked-in 60-year design life reflected in conditions of project funding, investor returns and customer/purchaser guarantees
- Giving incentive to large scale Smart Building through streamlined planning and approvals processes.

Impact and Benefits

- Impact grows from today's low base to high by the end of the decade. The enhanced image relies upon, and is a consequence of, the prior recommended actions. Over time, however, the newer more positive image feeds a virtuous cycle in which concrete positive demonstrations of transformation raise public expectations, and in which rising expectations in turn contribute to further industry innovation.

Key Players

- Governments, industry, education and training.

Our Vision, Our Objectives: 2023-2033

Over the coming decade, we will aim for an Australian Smart Building industry of growing size and significance that helps all citizens achieve secure, quality, affordable housing, while increasingly servicing middle market demands for diverse options and additional amenity.

An industry providing benefits of higher productivity, speed and quality to Australians' housing needs, as well as to essential public infrastructure and services (health and education facilities), and to the needs of the industrial, logistical and commercial sectors.

An industry that contributes significantly to Australia's environmental and climate goals, through buildings with dramatically lower embodied carbon, higher resource efficiency in production, superior design, and greater energy and water efficiency over their entire lives. A Smart Building sector aligned to an ageing population remaining in their homes in comfort, security and in inclusive communities.

An industry that responds to the need of the Australian economy for greater diversity and new knowledge intensive industries, incorporating digital manufacturing technologies and new business models into construction, to supply the Australian community with attractive, quality multipurpose buildings, with high functionality and amenity.

A building sector that is smart not only because it uses smart technologies and methods in production, but also smart digital technologies enabling buildings to perform to high standards of energy and resource efficiency throughout their lives.

By 2033 a series of successful Smart Building projects has transformed public perception and confidence to embrace prefabrication as a high-quality fit for purpose choice – a value proposition of superior quality, cost- and time-advantages.

By 2033 the sector forms a coherent and highly capable value chain embedding integrative digital technologies from upstream (DfMA) to production and assembly, using low carbon materials and technologies to provide high climate-performance design and through-life performance. Smart Building is a leader of Australian industry's decarbonisation push, together with showing the way to greater affordability and inclusive communities.

Smart Building Targets 2023-2033[11]

Australia's Smart Building Revolution will see transformation of the sector over the decade to 2033. Our ambitious targets reflect this major change. These targets can be achieved through the above-recommended actions. The targets reveal the immense benefits that prefabrication and Smart Building can deliver to Australia's economy, society and environment, through focus, planning, strong partnerships, and strategy and policy.

T1	Sector growth	Smart Building growing from 15 percent of total construction sector in 2025 to 30 percent in 2033.
T2	Sector growth	Prefabrication provides most public sector construction by 2033.
T3	Production, manufacturing	80 percent of building elements (facades, structures, wet areas and services) manufactured off site in smart factories – the preferred construction methodology for the built environment.
T4	Affordability (production)	Through achievement of scale (30 percent of total construction and most public sector construction by 2033, as well as providing 50 percent of the 2030 NHA build), deliver savings in production of 20 percent.
T5	Affordability (through-life)	By 2033 demonstrate a minimum 20 percent prefabrication life cycle cost advantage over conventional.
T6	Productivity	By 2033 Smart Building has demonstrated a 20 percent cost advantage over conventional construction.
T7	Productivity	By 2033 Smart Building has demonstrated a home construction time advantage of 12 weeks over 12 months for a conventional build.
T8	Resource efficiency	By 2033 Smart Building has demonstrated a 50 - 80 percent reduction in waste on the way to net zero and UN Sustainable Development Goals.
T8	Carbon reduction (production, embodied)	By 2033 Smart Building has demonstrated a 50 - 80 percent reduction in embodied carbon on the way to net zero and UN Sustainable Development Goals.
T 9	Carbon reduction (Responsible steel)	By 2033 agreed levels of responsible steel content mandated for all major public and private sector projects.
T10	Carbon reduction (through-life energy efficiency)	By 2030 commence production of 10-star energy rated buildings and homes.
T11	Towards carbon neutrality - DfMA	Mandated use of DfMA in all public and private sector major projects to provide digital truth and tools to confirm use of low carbon materials and methods, together with low carbon through-life performance.
T12	Digitalisation and DfMA	By 2030 DfMA is mandated to achieve digital integration and DfMA for all major public and private projects - automated design, AI - the industry standard leading to increased delivery innovation and continuous improvement.
T13	Circular Economy	Consistent with a 50-80 percent reduction in waste by 2033, have a recognised comprehensive national policy for the Circular Economy in construction, including targets for: • Use of recycled materials in new buildings • Standards for the minimum operational efficiency and life of specific products and modules and pods, and for their end-of-life reuse or recycling • End-of-life disassembly of a building or structure, and recycling, reuse, or repurposing of key components and materials.
T14	Inclusive workforce	Our industry is a preferred employer for diversity, equity, inclusion and being women-friendly.
T15	Strategic public procurement favours Smart Building	Starting with the NHA and the 1.2 new homes aspirational goal, prefabrication and Smart Building provide the majority of all public sector construction by 2033 .
T16	National Housing Accord (NHA)	By the final NHA year (2030) prefabrication and Smart Building account for at least 50 percent of the 2030 build.
T17	Other major projects	• Australian prefabrication supplies 50 percent of the build for the $2 billion package announced at the cancellation of the Melbourne Commonwealth Games (sporting infrastructure and regional housing) • Australian prefabrication supplies 80 percent of the build for the 2032 Queensland Olympic Games athletes' village • DFAT mandates use of Australian prefab solutions for the replacement of the Pacific Islands assets as well as critical consular and diplomatic facilities • Recognising the security advantages of offsite construction, Australian prefabrication supplies most of the construction requirements of the Australian Defence Forces throughout the decade.
T18	Business creation	By 2033 treble the number of businesses in the Smart Building value chain and achieving Smart Building accreditation, against 2023-4 baselines and benchmarks.
T19	Changing shape of the market	Against benchmarks established by earlier biennial surveys of major companies, governments and home buyers, by 2033 majority acceptance has been achieved in each market segment concerning the superiority of Smart Building over conventional construction.

11 Unless otherwise stated, targets are for achievement by 2033.

Building the future we want

The need has never been greater. This Smart Building industry roadmap is intended to help set the directions and leadership needed to realise the potential of prefabrication and industrialised construction.

The roadmap is addressed to all those whose active support and partnership are critical for success and for Smart Building to grow: industry, unions, governments, education, training and research bodies, the finance sector, and others.

Working together, we can build the future we want.

1. What is prefabrication?

What is prefabrication, industrialised construction, or Smart Building? At its most basic, prefabrication is simply production of parts of a building structure offsite and away from where the building will eventually be. These components and modules are brought on to site late in the process for assembly into a complete building. This demands high levels of standardization of modules, components and products.

The extent of offsite construction is a basic measure of the extent of prefabrication in a project. But today's global prefabrication industry is about much more than simply doing conventional construction in the old ways offsite. That is to say, it is no longer about using conventional production onsite methods only performing them offsite.

Instead, across nations and continents, prefabrication is transforming the construction sector from top to bottom. Prefabrication joins up construction with manufacturing. This is captured in the definition of industrialised construction as: "prefabrication, modularization and standardization of construction processes and assets within controlled factory environments" [12].

The conventional construction sector too may benefit increasingly from productivity improvement and cost reduction through hybrid models involving greater use of digital technologies and prefabricated parts, components and modules.

12 KPMG (April 2016) Smart Construction – How offsite manufacturing can transform our industry.

Today's prefabrication is Smart Building.

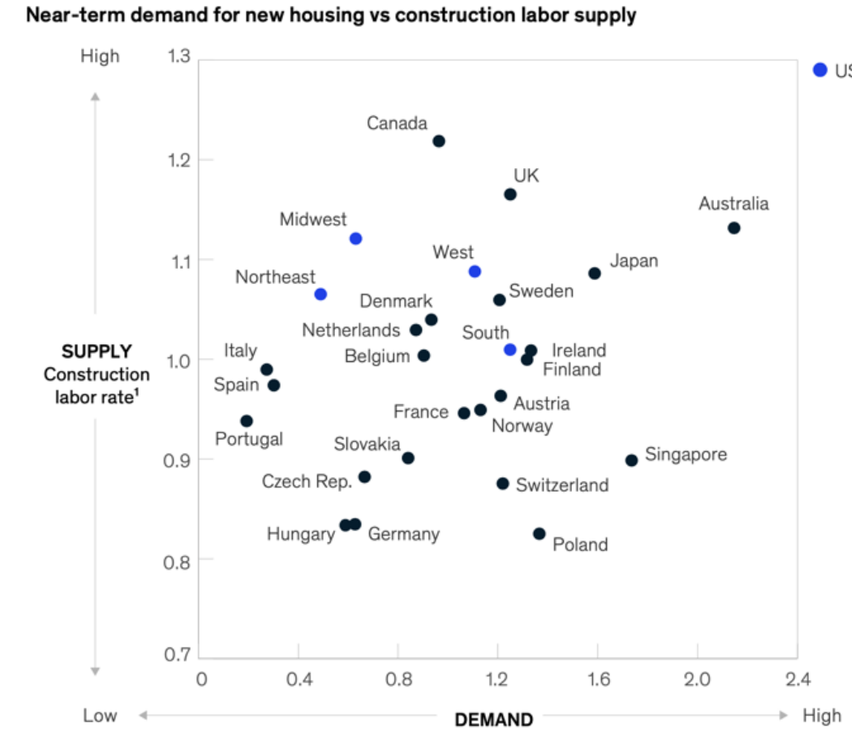
And today, this joining up of construction with manufacturing, requiring greater standardisation and precision in production, means a critical role for the ever-evolving Industry 4.0 digital technologies, that have so transformed manufacturing and industry supply chains over the past decade, in association with new innovative business models. Digital manufacturing, Industry 4.0, is a perfect fit with prefabricated production.

Between 70 and 80 percent of building production today can be offsite [13]. This is because digital technologies allow much greater precision in production processes, greatly expanding the scope for modularization and standardization.

Prefabrication exists as two predominant types: 2 Dimensional components that are assembled on site, such as wall units, and 3 Dimensional volumetric units, such as bathroom pods, which are dropped into the larger construction. Each has trade-offs, which will be examined later.

The main prefabrication materials are steel, timber and concrete, or hybrids of these[14].

Figure 1: Australia lags but is primed for take-off



Source: McKinsey (June 2019) Modern Construction: From Projects to Products.

13 McKinsey (June 2019) Modern Construction: From Projects to Products.

14 Ibid.

2. Prefabrication in Australia and the World

The nation lags significantly in prefabrication take up. But Australia's construction needs (especially housing) are defined by acute unmet demand alongside shortage and high cost of construction labour. This conjunction primes Australia for prefabrication take-off. The sector needs to grasp the potential of digital technologies integrated with new business models. It also needs a national policy partnership to set directions and goals. Australia can learn from other nations' positive approaches.

This Prefabrication Roadmap is intended to shape the future directions, partnerships and leadership needed to make the most of the opportunities coming Australia's way. But from where are we starting?

At less than 5 percent of total construction, the take up of prefabrication and Smart Building in Australia lags many other advanced economies.

But the two strong drivers for prefabrication takeoff – unmet housing demand alongside limited supply of construction labour – are very strong in Australia, as shown in the above chart.

Australian prefabrication is currently concentrated in provision of education, health, commercial and other infrastructure, with low penetration into housing. However, it is here that Australia's largest Smart Building opportunities are to be found. Capitalising on these will in turn create flow-on capabilities and benefits for prefabrication and Smart Building across the entire construction sector.

The many potential benefits from offsite production and construction are discussed below. The dominant benefit comes in helping deliver higher productivity to fulfill unmet demand – especially in housing – alongside limited supply of labour. Australia's combined acute shortages of housing and construction supply with shortages of construction labour favours expanded prefabrication, with its productivity advantages over conventional construction.

Several reports point to the lagging productivity performance of the construction sector internationally [15].

The productivity advantage of prefabricated industrialised construction has been multiplied over the past decade by the rise of digital manufacturing technologies or Industry 4.0, which has extended the potential productivity advantages of offsite construction over conventional construction.

That challenge will be met not only by bringing more production and construction offsite, but more fundamentally, by grasping comprehensively, the potential of digital technologies integrated with new business models.

Hence nations already with advanced prefabrication sectors are renewing their approaches and recommitting to policies that use prefabrication to achieve multiple benefits, from lower carbon footprints to greater affordability, housing security and social inclusion. Many lagging nations such as the UK have now developed active policies to catch up. Australia lags but as yet without the strong policies needed to catch up.

15 McKinsey (June 2019) Modern Construction: From Projects to Products. op cit.; KPMG (April 2016) Smart Construction – How offsite manufacturing can transform our industry; The Farmer Review of the UK Construction Labour Model. Modernise or Die: Time to decide the industry's future, October 2016.

SMART BUILDING: INTERNATIONAL PERSPECTIVE

Finland, Norway, Sweden: 45 percent; some estimates as high as 80% of Scandinavian houses built offsite. Sweden makes particular use of green building regulations

Japan: 15 percent of all current production; high quality; mature market; largest prefabrication market in world. Associated with quality and earthquake resilience, reinforced by inspections regime

Singapore: Very high, based on high-rise apartments; very high rates of home ownership, focus on public and affordability; mandated requirements for prefab in major public projects; conditional land releases to private sector. Major fund, with Construction Productivity Roadmap and Construction Industry Transformation Map, and mandating of DfMA

Europe: 15 percent

Germany: Estimates vary between 10 and more than 20 percent; distinctive for high single-family component, c.f. two-family & multi-storey. Modular demanded at single home level as higher quality product

China: 6 percent, but policy seeking to raise this to 10 percent in designated areas, 15 percent in others; driven by green push; based on high-rise apartments

Australia: 5 percent with target of 15 percent by 2025; some initiatives (including states), prefabAUS, AMGC, Building 4.0 CRC, Asia-Pacific Research Network for Resilient Affordable Housing, Prefab Innovation Hub, NRF, 1.2 million new homes policy, but no national strategy for Smart Building yet

UK: 5 percent; a laggard, but now trying to catch up; mandated prefab for large scale developments and land releases; mandated BIM standards; Construction 2025

USA: 3 percent, but significant rising demand, particularly on west coast

Policies: Large scale procurement and land release conditional on specified use of prefabrication; Innovation- and Green-Public Procurement; inspections and certification regimes underscore quality and public confidence; targeted sectoral programs and policies (e.g., UK Construction Sector Deal); support for resource efficiency; promotion of Industry 4.0

Sources: McKinsey (June 2019) Modern Construction: From Projects to Products; KPMG (April 2016) Smart Construction – How offsite manufacturing can transform our industry; Mordor Intelligence (various), AMGC (ND) Prefab Innovation Hub: Feasibility Study. Submission to the Department of Industry, Science, Energy and Resources; Office of Projects Victoria, Offsite Construction Industry Analysis. Digital Build Program, 2021.

A recent international survey finds "Although modular construction is currently used for only about 5 percent of new homes in Australia, the right conditions appear to be in place, since the country has both high construction wages and great unmet demand for housing. Most of the offsite manufacturing that takes place today uses relatively basic manual production lines, but there is increasing interest and investment from leading players" .

McKinsey (June 2019) Modern Construction: From Projects to Products, p 14.

In Australia the conjunction of high unmet demand and constrained labour and skills provides the potential and incentive to rapidly build the scale required for a successful prefabrication sector. But our existing sector must grow in capacity and capability, by adopting new digital technologies and new business models, expanding from 'projects to products', bundling products with new services, and embracing new climate-friendly materials and technologies. The necessity for expanded manufacturing and assembly capacity and capability stands out.

Australia has a cohort of leading and innovative businesses supplying high quality prefabricated solutions to the market. Nevertheless, our low take-up rate of prefabrication reflects an industry model still largely focussed on basic and remote housing, and in which prefabrication corresponds to the basic definition of offsite production, yet to take on board the new processes and models at scale. For the most part, Australian prefabrication takes traditional construction into the factory.

High rates of modular and prefabrication in the Scandinavian countries and others such as Japan and Singapore correlate to a high standard of design, production and building. These high standards are underpinned by economies of scale and scope, allowing mass customisation of designs and structures. They reflect adoption of new digital technologies and processes applied to create a growing array of new products and services.

In the UK, low take-up is due partly to perceptions of inferiority and post-war associations of prefabricated housing with shortages and austerity. But the UK is now pursuing active policies to promote the growth of prefabrication, in part due to labour shortages caused by Brexit [16].

Policies in leading high prefabrication nations emphasise mandated levels within major projects, use of large-scale public procurement to promote innovation, green objectives and resource efficiency, inspections and certification regimes that reinforce quality and public confidence, and sectoral policies and programs targeted to prefabrication, including digital adoption. Land release for major developments is sometimes made conditional on deployment of prefabrication and Smart Building (e.g., Singapore) [17].

Australia has important initiatives at state government level, together with increased collaboration between organisations such as prefabAUS, the Advanced Manufacturing Growth Centre and Building 4.0 CRC, to develop future industry directions. The Asia-Pacific Research Network for Resilient Affordable Housing connects companies and leading universities in 15 countries across the Asia Pacific, with a remit to help rapidly develop

16 The Farmer Review of the UK Construction Labour Model. Modernise or Die: Time to decide the industry's future, October 2016.

17 See Attachment 2 for greater detail on international policies promoting Smart Building.

new prefabricated materials that are cheap, light, reusable, durable, rapid to market, energy efficient and resilient to natural disasters. The Prefabrication Innovation Hub seeks to develop a distributed national network of services and facilities to further the Smart Building sector.

Nationally there is new recognition of the imperative of Australian reindustrialization, principally through the NRF, which has various touchpoints to prefabrication, and recognition is growing of the prefabrication sector's potential not only as a source of new industrial growth, but also as an aid in addressing a range of society wide challenges. The commitment to build 1.2 million new homes also presents opportunities to apply industrial methods and solutions at scale.

But there is not yet a national dedicated prefabrication strategy. For Australia, there has not been a time in which the need and the opportunity were greater.

3. Why prefabrication?

At the level of individual businesses and the industry sector, prefabrication and bringing together construction, manufacturing, and Industry 4.0 means transformational potential, with opportunities for new products, greater production efficiency, higher productivity, reduced waste and higher utilisation, shorter construction times, new business models, and better margins.

For the Australian economy, needing to broaden its industrial base, prefabrication promises to help create a whole new value adding industry for Australia.

Building this sector creates further benefits for Australian society. Prefabrication helps address such social and environmental challenges as housing affordability, climate resilience and adaptation, and carbon reduction through low or no carbon materials, greater energy efficiency and better design.

Australian prefabrication is poised for uplift. Its productivity advantages over conventional construction particularly mean it can help overcome Australia's structural supply-demand problems described previously. The nation can move from laggard to leader on the international prefabrication tables.

a) The benefits and opportunities of prefabrication: productivity, speed and bottom lines

In production prefabrication offers benefits of higher productivity, lower waste and higher resource efficiency, production efficiencies, time- and cost-reductions, and supply chain optimisation.

Prefabrication's higher productivity over conventional onsite construction sector comes particularly from its ability to utilise fully new digital technologies and business models. The capacity to deploy fully Industry 4.0 and apply new business models is not available to conventional construction, perhaps beyond Building Information Management (BIM).

One study, focused on dwellings only, says prefabrication can cut construction times by as much as 50 percent and reduce costs by up to 20 percent[18]. Another analysis estimates smaller cost reductions of 7 percent. The same report claimed offsite construction is three-times more productive than onsite[19].

A further study, which took in the whole spectrum of prefabrication applications from housing to schools, hospitals, commercial premises, and so on, found potential for "a transformative five- to tenfold increase in productivity ... if construction were to move to [a] manufacturing-like system of mass production with a much greater degree of standardization and modularization and the bulk of construction work taking place in factories off-site".[20].

These widely diverging estimates point to an opportunity. That different measurement methodologies or different projects suggest different magnitudes of benefit should not obscure the fundamental point.

Australian conditions may also imply different quantitative estimates of benefit. A 20 percent cost advantage implies an annual $9 billion benefit across the Australian economy from 2033, if the target of a 30 percent Smart Building share of total construction can be attained (in current prices)[21].

Offsite construction is not disrupted by the weather. Production can occur all year, over more than one shift, achieving high utilization of plant and equipment. High utilization rates help to justify the initial investment in new technology.

The factory environment can be made much safer than onsite, with fewer days lost to injury. Offsite construction allows more things to be done simultaneously, such as foundations and walls, and to be integrated later onsite.

Use of digital technologies can only occur extensively in a factory environment, providing greater precision and accuracy in estimation of costs and delivery times.

Process control technologies and automation reduce time and waste, reducing defects and rework. Tradeoffs need to be made to make these gains, and these are discussed below.

Finally, shorter prefabrication construction times translate to earlier realisation of revenues and profit, while higher productivity brings the promise of better bottom lines.[22]

b) The benefits and opportunities of prefabrication: quality, sustainability, affordability, energy efficiency and resilience

Prefabrication offers Australia the benefits of a new knowledge-intensive industrial sector together with a range of social and environmental benefits:

- higher quality
- affordability gains
- superior environmental performance – in production and throughout the building's operational life
- greater resilience in a changing climate – fire and flood resistance and survivability, emergency accommodation
- designing and building for inclusive communities – population ageing
- lower lifecycle costs

New business models: From individual projects to products and services:

- Mass customisation
- New materials, new engineering practice
- Population ageing/smart homes/ assistive technologies
- Home automation/systems integration
- New product and service opportunities, with greater complexity and sophistication

Today the potential market for prefabrication spans a broader array of housing and construction requirements than ever before. Compared to the past, prefabrication is no longer a compromise on quality, nor focused primarily

18 McKinsey (June 2019) Modern Construction: From Projects to Products.

19 KPMG (April 2016) Smart Construction – How offsite manufacturing can transform our industry.

20 McKinsey Global Institute (February 2017), Reinventing Construction: A Route to Higher Productivity, p 115.

21 See Attachment 1 for detail on this conservative estimate.

22 Although it is only prefabrication that allows full realisation of the productivity benefits from digital technologies, the wider conventional construction sector also can gain through growth of prefabrication and adoption of hybrid models. Prefabrication can enter the conventional sector through greater use of prefabricated standardised parts, components and even 2-D and 3-D modules.

on remote housing or other highly cost-sensitive market segments.

To the contrary, prefabrication is a new sector responding to multiple complex problems through greater innovation, specialization and a growing, diverse array of products and services, with positive opportunities for diversification of Australian industry.

Prefabrication is a platform to help address a range of pressing needs facing all of us.

In addition to prefabrication's production and productivity benefits, the growth of this new sector can be hitched to the large-scale trends and policies and programs that will create high demand and greater opportunities for the prefabrication industry.

Australia's challenges of affordable housing, of an ageing population, of reducing the carbon footprint and energy efficiency of our buildings, and of building their resilience to future fire and flood events: all favour prefabrication.

Through the greater precision of construction and various components entailed in prefabrication and Industry 4.0 applications, prefabrication offers potential gains in quality over conventional methods.

Gains in housing affordability arise from lower production costs and faster production and construction, together with the fact that the affordability-related trend to higher density new urban development is perfectly aligned to prefabrication.

Affordability is not only a matter of lower production costs translating to lower housing purchase costs. It is also about realising gains and savings through lower lifecycle costs, particularly energy. One study sees prefabrication boosting affordability through savings in lifecycle costs of up to 25 percent [23].

Prefabrication offers prospects for major gains in environmental sustainability and climate performance, both in production and performance over time. In production and construction, prefabrication linked to Industry 4.0 applications increases resource efficiency and reduces waste. Fewer materials are consigned to landfill. Offsite production reduces carbon miles expended. Prefabrication also expands potential for use of recycled materials compared to conventional construction.

Again, prefabrication design and production characteristics allow greater energy efficiency and a lower carbon footprint to be designed-in and built-in for the whole operational life of the building. Regarding climate adaptation, prefabrication offers greater resilience in a changing climate, with higher ability to design and build for greater fire and flood resistance and survivability, together with application to emergency accommodation.

These features of prefabrication also open up spaces for the use of new materials and new engineering practices.

Through scale and precision, prefabrication can offer superior models for an ageing population to live in inclusive and vibrant communities.

These examples illustrate the potential to create a virtuous cycle in which climate and ageing needs and concerns promote the development of new products and services, in turn acting as a stimulus to new industrial opportunities and development.

With prefabrication's capacity to facilitate mass customisation of buildings, especially residential buildings, comes opportunity for new product development associated with new services that enhance the product. These often involve digital control and performance and condition monitoring systems for internal climate, use of assistive and mobility technologies to assist the ageing, remote health monitoring of older residents, and so on. Digital technologies are concerned with how well the building functions through time, not only how it was constructed.

Systems integration, home automation, and a range of new product and service business opportunities arise from prefabrication and Smart Building.

The opportunities are for new product development bundled with ongoing services and revenue sources. This presents individual businesses and the sector with the challenge and opportunity of innovating their business models, finding new sources of value to the market that will lock in customers and provide enhanced ongoing business revenues. The sector needs to broaden its focus from individual projects to projects, products and services.

23 McKinsey (June 2019) Modern Construction: From Projects to Products.

4. Industry 4.0 and prefabrication

The array of digital technologies known collectively as Industry 4.0 are the enablers for take-off in prefabrication, allowing precise translation of designs, higher resource - and production - efficiencies, the emergence of new business models, and new products and services, and stronger margins and bottom lines. Industry 4.0 digitalises enterprises and the whole supply chain to integrate the operations of people, machines and things. Industry 4.0 creates an unprecedented requirement for coordination across the entire supply chain, setting standards that each business must meet to capture emerging prefabrication opportunities.

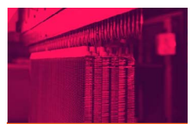
Industry 4.0 is the digitalisation of enterprises and whole value chains, through the real-time integration of people, machines, and things. It is the use of cyber-physical systems, and the end-to-end digitalisation of enterprises and whole value chains. Manufacturing becomes data-driven.

The key elements of 4.0, the industrial internet, or, the fourth industrial revolution, are: the IoT and everywhere low-cost sensors to connect machines and devices; robots that can now work with the employee; artificial intelligence and simulation and digital twinning; and the exponential rise in data processing power known as Big Data.

What is Industry 4.0? Enabling technologies

Sensors and data analytics

- Across whole value chain
- Predictive maintenance
- Logistics tracking
- Quality control

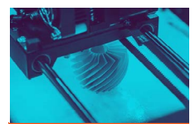


Advanced materials

- Proactive not reactive
- Integrated at design
- Multiple attributes

Smart robotics and automation

- Assistive
- Human collaboration
- Awareneess, decisions
- Full autonomy



Additive manufacturing

- Complete, complex, products
- Lower capital investment
- Consumer led design
- Just in time production

Augmented and virtual reality

- Overlay designed with environments
- Optimised equipment
- Remote collaboration
- Safe training

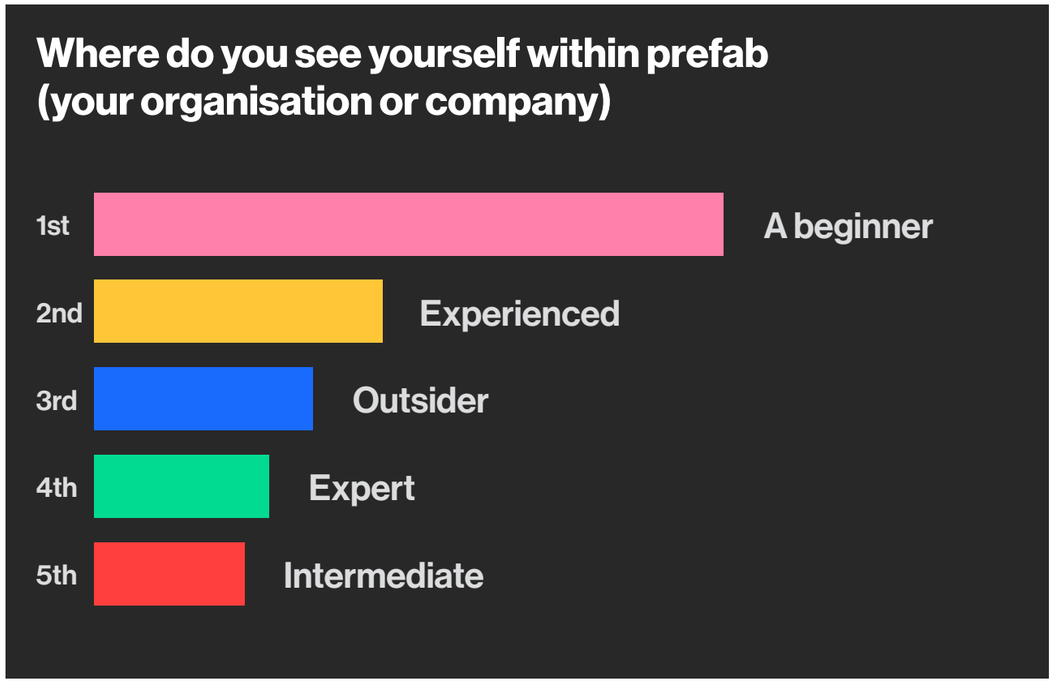
CSIRO

All of these - automation and robotics, advanced materials, sensors and data analytics and augmented and virtual reality – have existing critical applications in the offsite construction industry, that will only become more critical in future.

What Industry 4.0 offers to prefabrication is: higher performance and productivity; rapidity and heightened responsiveness to the market; taking out whole layers of costs; allowing the emergence of new business models often focused on bundling and enhancing the value of a product through additional services; potentially locking in customers and capturing additional value for businesses in the prefabrication sector.

These are the benefits offered by Industry 4.0. Conversely, the failure to adopt digital technologies has severe implications. Industry 4.0 creates highly integrated, interdependent value chains. Industry 4.0 is not an optional extra for prefabrication businesses. Industry 4.0 competences are today mandatory, whether you are an offsite industrial constructor already, or if you seek to become one. Increasingly, digital technologies are creating new norms and standards for all parts of the prefabrication industry. Meeting the basic requirements determines whether a business will be able to take advantage of the new opportunities, or whether it is frozen out altogether.

Our industry workshops found that while a significant proportion were either experienced or expert in applying digital technologies, the largest cohort are beginners. But the workshops revealed the industry's enthusiasm for greater digital adoption.



Industry 4.0 technologies are changing each link in the Smart Building value chain: creating greater and greater integration and interdependency of each value chain link with all the others.

A recent report[24] assesses the nature and extent of digital technologies in construction in Australia, Japan and Singapore. The survey covers all construction methods – conventional and Smart Building. However, it should again be noted that the full productivity and other benefits of Industry 4.0 and digital technology can only be realised through prefabrication and offsite production. The report summarises the suite of construction-relevant digital technologies as:

- 3D printing
- Artificial Intelligence and Machine Learning
- Augmented and Virtual Reality
- Blockchain
- BIM
- Concrete non-destructive testing
- Construction management cloud software
- Construction wearables
- Data analytics
- Digital twinning
- Drones
- Internet of Things (IoT) and Smart Sensors
- Mobile apps
- Prefabrication and modular construction
- Robotics and Automated systems
- Sustainable Building Materials.

With the following providing the principal benefits at the individual enterprise level:

- Increased productivity
- Improved customer experience
- Staff safety
- Reduced costs
- Increased quality
- Expansion into new markets
- New projects and increased revenue
- Improved regulatory compliance and reporting
- Enabling innovation
- Informing company strategy.[25]

24 Deloitte Access Economics (March 2023), The State of Digital Adoption in Construction Report 2023.
25 Ibid.

SUCCESSFUL DIGITAL ADOPTION NEEDS A DIGITAL STRATEGY

Adoption of digital technologies by Australian construction businesses is gaining momentum. BIM and DfMA are growing in application. Use of VR and AR is spreading. Drones are in increasing use for survey and navigation of building sites. In production, robotics and automation are setting the standard for resource efficiency, precision and quality. Cheap sensors are being deployed both in production and in the efficient operation of the building.

Luyten is an Australian company that has produced the first building code compliant 3D printed house in the southern hemisphere. The building took two days to print and one day to assemble. (Ref: AMGC (ND) Prefab Innovation Hub: Feasibility Study. Submission to the Department of Industry, Science, Energy and Resources.)

FormFlow uses digital production technologies to bend corrugated metal sheets that eliminate gaps and joins and, in so doing, helps protect against ember attacks during bushfires and against moisture penetration during severe tropical storms, and achieves improved insulation against draft and the elements.

MODSCAPE has embraced DfMA and recorded significant benefits over a 15-year period, including: a 50 percent reduction in project and build times; higher quality; an 80 percent reduction in waste compared to conventional construction, coupled with significant lowering of carbon emissions; a safer environment; and significant cost savings. (Ref: PrefabAUS, Adoption of Design for Manufacturing Assembly in Prefab Construction, October 2022. Project Funding Agent: Advanced Manufacturing Growth Centre Ltd.)

The company has announced significant new investment in a bespoke production facility using robotics and high automation developed in Sweden for Ikea.

While the array of digital applications is growing and cost of applying digital technologies is falling, barriers remain to full take-up. The main impediments are the significant differences between traditional building and prefabrication, and the informational barriers and misconceptions that hinder digital adoption in manufacturing generally, especially for SMEs.

Businesses large and small need digital strategies that set objectives, take stock of existing resources, assess risks, and define the stages that must be gone through to progress from 'the now' to the desired future state. This is the opposite of 'all or nothing', instead identifying low risk early steps and actions to pilot and trial innovations: starting small and scaling up over time. This means considering such questions as:

- What existing machines could be connected digitally? Where could we fit sensors? How could this benefit our production efficiency or help us develop a new product or service?
- What services do we link with our products, and can this be enhanced?
- What digital technologies do we use now, what data do we collect now, and can we do more with it?
- Could this be enhanced to add revenue and provide lock-in with key customers?
- What about the digital skills of our workforce?
- How can we move to higher value service content alongside our products? How does the business change from a mindset of just production and unit cost, to lifespan, lifetime performance and use?
- How do we create awareness and alignment across the business, do we have leaders ready to step up? ? What structures, teams and processes are needed? What goals should be set? What timelines should be set?
- How do we scale the project to reduce risk?
- How do we stage a phased transition to Industry 4.0? What are the defined developmental stages our strategy needs?

Most of all, a digital strategy should not be about the technology alone, but about combining digital possibilities with new business models and markets.

5. Business model innovation in construction

Prefabrication is the form of construction which allows the building sector to maximise the use and benefits of digital technologies. Additionally, prefabrication allows full use of digital technologies to provide important ongoing services to be bundled with the building. Prefabrication becomes Smart Building. Industry 4.0 is about production guided by digital technologies. Industry 4.0 is also about new products combined with ongoing delivery of a service. Just as sensors are used to optimise and radically reduce waste in production, so too cheap sensors associated with ongoing service provision can lead to new products that can extend markets and add to business revenues and margins. Prefabrication lends itself to making smart homes and buildings, automated homes and buildings.

Just as sensors monitor the condition and performance of equipment in production, so too can they be designed into monitoring the performance of the completed building, and the health and comfort of its occupants. This is of great importance especially to service provision to an ageing community.

Adding services to the products a business makes can be a vast opportunity. This can be done using sensors and cloud-based services.

The same applies to the climate performance of the building. On a service-enhanced model, beyond installation of the hardware, a service guarantee contract can be offered concerning ongoing levels of performance and comfort. This offers to run the hardware to a certain optimum ongoing performance as a service.

The business model is reconfigured from a single transaction (sale) of the product repeated as often as possible, with a longer-term relationship between producer and purchaser underpinned by the bundling of services with the product(s). It becomes a product-service model. This may require a business's revenue model to go from profit on sale to revenue extended potentially to the end of the life of the product, or its reuse, remanufacture or recycling. Between production of the product and its end of life, the vendor may have provided condition and real-time performance monitoring, preventative maintenance (using sensors and other digital technologies), and through-life modular equipment upgrades. For both vendor and purchaser, a relatively larger part of the revenue or cost of providing the product comes from the associated services compared to production costs.

Japan is a leader in both prefabrication and the 'bundling of buildings with services'[26] provided throughout the building's life. Systems of 'home guarantee' and 'after sales and maintenance services' utilise prefabrication's modular character to provide through-life support, including:

- Upgrade services: detailed plans and data are used to monitor component condition and recommend which should be inspected or replaced.
- Renovation and reorganisation services: replacement of units or additions to them in line with changes in lifestyle or household size or needs.
- Customizable energy platforms: electronic controls of water and energy systems and use in the home.
- Personal assistance technologies: sensors, actuators and assistive technologies that support greater ease of living, especially for older inhabitants or those with health conditions.

26 Evolution of large-scale Industrialisation and Service – Innovation in Japanese Prefabrication Industry, Journal of Construction Innovation: Information, Process, Management, Volume 12, Issue 2, Emerald Group Publishing Limited 2012.

- Reverse logistics and re-customisation: deconstruction of building components at end of life. Some Japanese companies offer trade-ins on their buildings for a new building from the company. This includes deconstruction of the building, transport to a dismantling facility, with modules and components reused, remanufactured, or recycled [27].

These examples of highly advanced servitisation point both to future trends and the vast potential for transformational industry growth.

CHAAS - 'COOLING AND HEATING AS A SERVICE'.

Australian firm SmartConsult provides services that change the relationship of heating and cooling industry to its markets. The consumer can choose to be charged according to how much an energy plant produces in heating and cooling units on a monthly basis. This provides incentive for the energy supplier to use energy-efficient plant and equipment. The system works for both greenfield developments and refits of existing houses, offices and facilities. Different energy sources (e.g., solar) are metered differently.

The company provides services relevant to a range of heating and cooling equipment and services such as PV solar and storage systems. Users are encouraged to save energy through 'Cooling and Heating as a Service'. This includes heating and cooling the building during off-peak periods and use of thermal storage. Through control of the mix of energy sources to deliver the most economic energy flows to the user, the supplier also is driven by energy-efficiency goals: the fewer energy units used compared to thermal output, the higher is the supplier's margin.

The model facilitates energy-efficient consumer choices based on lifecycle costs rather than on upfront equipment costs.

(Material provided by Advanced Manufacturing Industry 4.0 Hub, Factory of the Future, Swinburne University of Technology, and Advanced Services Group).

27 Ibid.

6. Key success factors: Scale, Repeatability, Trade-offs[28]

Gaining the benefits of prefabrication requires a focus on the right projects, involving larger scale, and high repeatability. Requiring precision, prefabrication involves a longer and more deterministic design phase over conventional onsite construction. This also allows mass customization. Tradeoffs need to be made. Prefabrication involves gains in production efficiency but also potentially higher logistics costs. Transport and logistics set limits on weight and size of 2D and 3D components, and favour high value to size (e.g., wet areas and bathroom pods).

How can Australia gain the benefits of prefabrication? Isolating the key factors for success for prefabrication means asking:

- Which types of projects allow full realization of the benefits of prefabrication and modular production?
- What are their core characteristics, and what are the trade-offs that need to be made and understood to make the potential gains real?

Prefabrication is the intensified application of industrial processes, especially Industry 4.0, to construction. Hence the key conditions for success are projects of sufficient scale (to justify investment in new technology and plant), and maximum repeatability. Standardisation is key.

Standardisation and scale do not mean uniformity of the finished product, any more than that the common platforms used to make automobiles mean that cars all look identical or do not vary in performance or amenity. Mass customization methods allow for variation to meet different user requirements. This capacity for mass customization is a major prefabrication advantage.

Gaining the advantages of mass customization hinges on the design phase, as does the capacity to reap economies of scale and efficiencies and cost savings in production. The prefabrication design phase is necessarily longer than onsite construction, and deterministic of subsequent production and construction processes. The design phase needs to establish precisely the characteristics of all the interdependent modules that will need to be integrated and consolidated onsite to create the building. In conventional onsite production, the design may be amended, workarounds used, and reworking needed. This is not possible in prefabrication. The design is an exact representation of what the building will be. This locks in the precision that allows more efficient production.

From offsite production to onsite installation and consolidation, prefabrication depends upon workable and affordable transportation and logistics. Prefabrication will often entail higher logistics costs over conventional on-site construction. Unless properly taken into account, these higher logistics costs can cancel or certainly reduce, efficiency gains in production.

This means, again, standardization and limits to the weight and dimensions of 2D and 3D modules. A further consequence is the importance of targeting for prefabricated components that exhibit high value to size, such as 3D bathroom pods.

These are the critical factors that must be considered in capturing benefit from prefabrication and determining what types of projects are most suited to prefabrication applications.

28 This section draws extensively from McKinsey (June 2019) Modern Construction: From Projects to Products.

7. Smart Building types and opportunities

The principal building types favourable to prefabrication are affordable housing, student accommodation, schools, hospitals, and hotels. Other building types can also benefit from prefabrication, contingent on specific conditions.

The principal Smart Building opportunities are those building projects most likely to deliver scale and repeatability. Scale and repeatability provide savings through factory-based production to compensate the higher logistics and transportation costs of prefabrication.

Logistics and transportation set the size and weight requirements of 2 or 3D modules to be brought on site. 2D modules pose fewer logistics challenges than 3D modules, where the implications for logistics costs of greater weight and volume favours small structures high in value, such as bathroom pods[29].

To be clear, prefabrication can still be applied even where standardization and scale are low[30]. In these instances, say a single house, prefabrication is likely to be 2D panels rather than more complex 3D modules. But it is in projects of larger scale requiring standardization, repeatability and cost reduction, that prefabrication can be applied intensively to deliver benefits, involving both 2D panels and 3D volumetric modules [31].

a. Residential dwellings:

- Affordable housing: High scale, high repeatability, size of units - high value for transport (affordable homes are smaller), high value small units (wet areas)
- Student housing: Likely high scale, high repeatability, size of units - high value for transport (smaller accommodation), high value small units (wet areas).

Beyond these high potential areas, multi-family dwellings may also be prefabrication-relevant, where sufficient scale and repeatability can be achieved. Alongside 2D panels, there is potential for incorporation of prefabricated 3D modules into hybrid projects, where the size and high value of units is favorable to transport (wet areas).

Single family dwellings are likely of low scale but may offer medium-value for size of units, medium-value for transport, medium potential for gains in high-value small units (wet areas). However, the main prefabrication application at relatively low scale will be 2D panels using optimised logistics.

29 Ibid.

30 In addition the conventional construction sector can benefit from prefabrication innovations through use of standardised parts, components and modules.

31 The following discussion draws on McKinsey Ibid, and AMGC (ND) Prefab Innovation Hub: Feasibility Study. Submission to the Department of Industry, Science, Energy and Resources.

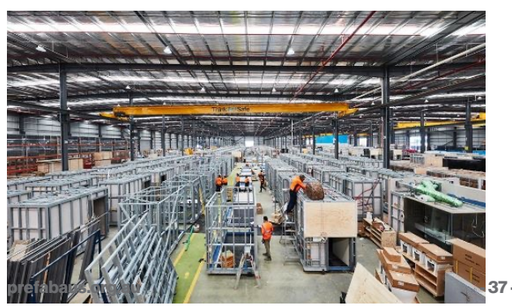
Holiday homes are an existing focus for prefabrication, with growth potential.

b. Commercial premises:

- Hotels: Scale contingent and variable, high repeatability, size of units high-value for transport, high potential for gains in high-value small units (wet areas) and narrower rooms. Full use of 2D panels and 3D modules.

Beyond the very high potential of hotels, a wide range of commercial uses such as offices, retail and logistics and warehousing retain high prefabrication relevance, especially where scale can be achieved. They vary as to repeatability and costs of and suitability for transport and value, as well as use of high value smaller units:

- Offices: high repeatability, size of units medium-value for transport, medium potential for gains in high-value small units (wet areas)
- Retail: medium repeatability, low-value for unit size as amenable to transport, medium-value for high-value small units (wet areas)
- Logistics/warehousing: high repeatability, medium-value for size of units, high-value for transport and high value small units (wet areas).



c. Public buildings:

- Schools: High potential scale, high repeatability, unit size good for transport, medium complexity, high value small units (wet areas)
- Hospitals: High potential scale, medium repeatability, high value small units (wet areas).

Both hospitals and schools are prime for full use of 2D panels and 3D modules. Other public buildings also have potential uses for prefabrication, sometimes with lower (though still significant) potential to benefit from repeatability and use of high value small units. These include railway and police stations, community centres, and sporting and correctional facilities.

Prefabrication's requirement for scale means that the sector's development can be assisted by directional and positive public policies such as advanced public procurement aimed at capturing Smart Building benefits that include cost reduction and affordability, faster construction, lower carbon impacts, greater climate resilience, better alignment to the needs of an ageing population, and greater use and integration of digital technologies. Advanced public procurement can build and aggregate the project portfolio in a planned and progressive manner, helping to leverage demand to build scale and sector capability.

8. The prefabrication value chain and Industry 4.0

The Smart Building value chain should be analysed as a combination of the level and character of supply side capacity and capabilities, with the range of demand-pull factors that can shape and set directions for the evolution of the industry.

A value chain is an interdependent set of links. Where these are disjointed or underdeveloped there is a lack of integration and opportunities will be missed.

A highly competent integrated value chain uses interdependencies and linkages positively to build capability and responsiveness to the market. Industry 4.0 has increased dramatically the level of integration and interdependency required of an efficient Smart Building value chain.

The following stylized and simplified Smart Building Value Chain consists of seven key stages:

1. **Design, planning**
2. **Inputs, raw materials, intermediate processes**
3. **Procurement, supply chain**
4. **Production, manufacturing**
5. **Assembly**
6. **Through-life support and systems**
7. **End markets.**

Industry sectors and value chains evolve and change in response to major economic, social, demographic, technological and environmental trends. The key trends that will shape the demand for Smart Building – and positively promoted as elements of a national strategy to shape, grow and develop the sector - are:

- The imperative of decarbonisation
- The growing unmet demand for affordable housing
- Population ageing
- The need for productivity improvement and resource efficiency in the construction sector
- The pervasive role of digital and Industry 4.0 technologies in revolutionising production
- The roll-on impact of digital technologies in multiplying available products and services, new business models that bundle services with products to lock in customers and provide additional revenue sources ('servitisation'), and
- Greater acceptance of positive roles for government and industrial policies in helping to set desired future directions for the economy.

These developments are favourable to greater Australian prefabrication and Smart Building, as is the fact that some parts of this sector may enjoy a higher degree of 'natural protection' against imports than other sectors[32]. This has likely increased due to Covid and will be more the case in future where the product (e.g., responsible steel and aluminium) will be required to have low or no embodied carbon. This is an additional factor favouring Smart Building for specific policy and program focus.

Table 1 provides a description of the components of each of the seven links and the critical role of Industry 4.0 with respect to each and the whole value chain.

32 Although this should not be assumed or exaggerated. Australia is highly import-dependent in high weight-to-value items such as concrete and steel, formerly thought difficult to trade economically over large distances.

Table 1: Value Chain components/links and Industry 4.0 technologies

Link 1 of the Value Chain

DESIGN, PLANNING

- DfMA;
- R&D;
- Problem solving/mgt.;
- Optimisation;
- Product testing/certification;
- Choice of Materials;
- Planning

BUILDING 4.0

- BIM, CAD
- Digital twin
- Simulation
- Product Lifecycle Mgt. (PLM)
- Virtual reality
- Cloud office apps

2nd Link of the Value Chain

INPUTS, INTERMEDIATE PROCESSES

- Raw materials;
- Value adding;
- Processing and manufacturing: Steel, Aluminium, Timber and Concrete

BUILDING 4.0

- Digital process technologies
- Sensors & data analytics
- Robotics
- Production controls
- Performance & condition monitoring of machinery
- Waste reduction, resource efficiency
- Digital controls for high energy needs

Link 3 of the Value Chain

PROCUREMENT, SUPPLY CHAIN

- Supply chain mgt. and logistics;
- Logistics tracking;
- Quality control & product specifications;
- Materials control

BUILDING 4.0

- BIM
- PLM
- Simulation
- Sensors and data analytics

Link 4 of the Value Chain

PRODUCTION, MANUFACTURING

- Production methods;
- Controls, optimisation and automation;
- Quality control;
- Resource efficiency

BUILDING 4.0

- Sensors/analytics
- Robotics
- Process technologies
- Additive mfg.
- Assistive tech
- Virtual reality for optimisation & collaboration

Link 5 of the Value Chain

ASSEMBLY

- Assembly systems;
- Integration;
- Electronics;
- IT;
- Energy systems;
- Ageing and assistive technologies

BUILDING 4.0

- Sensors/analytics
- Robotics
- Process technologies
- Assistive tech.
- Virtual reality
- Optimisation

Link 6 of the Value Chain

THROUGH-LIFE SUPPORT AND SYSTEMS

- User analytics;
- Condition monitoring;
- Predictive maintenance;
- System upgrades;
- Energy systems

BUILDING 4.0

- Sensors & data analytics
- Cloud/Internet of Things
- Ageing/assistive tech.
- Climate telemetry/Performance

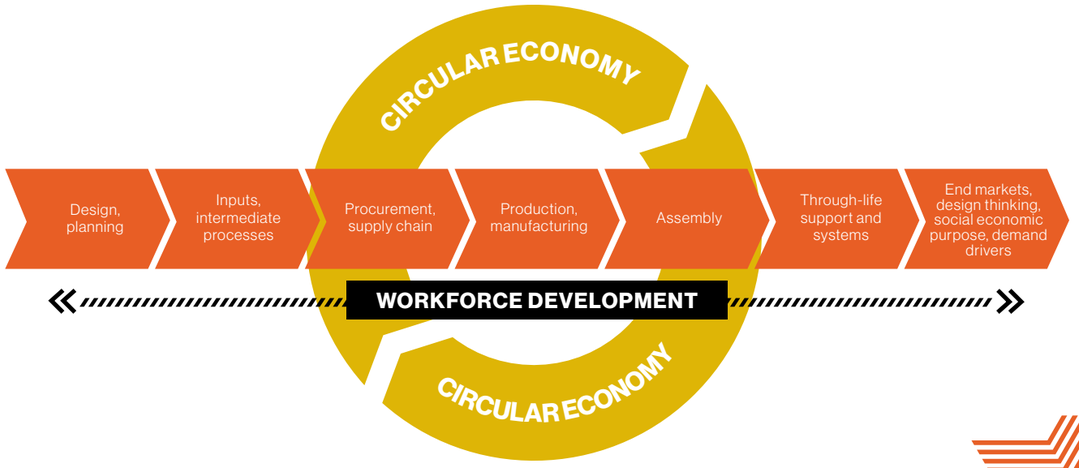
Link 7 of the Value Chain

END MARKETS, DESIGN THINKING, SOCIAL-ECONOMIC PURPOSE, DEMAND DRIVERS

- Public procurement;
- Industrial policies;
- Regulation; Industry standards;
- Financial sector norms and practices;
- Capacity for positive market shaping

BUILDING 4.0

- BIM
- DfMA
- Digital twin
- Simulation
- Product Lifecycle Mgt. (PLM)
- Whole of life costing
- Digital promotes scale and aggregation of demand



The Smart Building value chain commences with a deterministic **design and planning** link (link 1), in which the parameters and requirements of subsequent stages are set. So is the critical role of digital technologies. Building Information Modelling (BIM) is now in wide use, but its applications have been extended by the explosion of digital technologies, as has also happened with Computer Aided Design (CAD). These now include the capacity to simulate the characteristics and performance of the structure before construction, creation of a digital twin to the physical building, and use of virtual reality to, amongst other things, improve the climate performance of buildings, as well as to improve resilience in the face of climate-related increases in the frequency and severity of floods and fires.

DfMA is the summary concept for upfront design processes that bring the stakeholders in a project together to determine the right manufacturing method and the right materials, ensuring designs are manufacturable, standardised, modularised, that operations are optimised, and so on. This includes Product Lifecycle Management (PLM), which plans the design, development, production, through-life support and eventual retirement of a product or component.

What DfMA brings to the manufacture of 2D and 3D components is optimisation and standardisation. DfMA allows functional standardisation, reduction in the number of parts, and consequent cost reduction. Although increasingly applied, DfMA is seen as held back by lack of skills within businesses, and by not being demanded sufficiently by lead customers[33].

In **inputs, intermediate processes** (link 2), which follows earlier choice of materials, digital technologies are used to optimise production, ensure precision, monitor the performance of equipment, minimise waste and maximise resource efficiency, including energy inputs for this energy-intensive stage, with increasing requirement for materials with no or low embodied carbon.

The **procurement**, **supply chain** (link 3) stage is similar to the design and planning stage in its mobilisation of digital technologies. It operationalises decisions embedded in design and planning beyond choice of materials.

Across much of the value chain, the role of sensors and analytics to provide real time information is critical. They are important to the procurement and logistics component of the value chain, especially for supply chain organisation and logistics tracking.

During **production**, **manufacturing** (link 4) sensors, robotics and automation especially, produce components exactly to size and specification, optimise production schedules, ensure high quality and minimise waste.

These technologies are also key to the onsite **assembly** (link 5) and consolidation of the structure, together with integration of smart systems governing energy use and efficiency to reduce carbon emissions, as well as achieving the potential of prefabrication to incorporate technologies helpful to an ageing population.

Industry 4.0 technologies are critical not only to how prefabricated structures are designed and produced, but also to how well they perform throughout their lives (**through-life support and systems** (link 6)). Cloud-based services allow sensors to analyse and monitor the performance of critical equipment and building services such as energy and climate control, and to detect problems before they become acute. Equipment can be maintained for longer efficient life through predictive maintenance, and system upgrades, when required, can be achieved more smoothly.

Finally, end markets (link 7) will send powerful demand signals for digital technologies throughout the value chain, as they will require efficient project delivery through DfMA, higher overall quality through product assurance and certification, lower embodied carbon and higher resource efficiency in production, and high environmental performance throughout the building's life.

33 PrefabAUS (October 2022), Adoption of Design for Manufacturing Assembly in Prefab Construction.

9. Australia's Smart Building value chain: Strengths and gaps

Australia's Smart Building value chain is disjointed, with significant capability gaps. The largest deficits are in **production**, **manufacturing** (link 4) and **assembly** (link 5). These weaknesses can be addressed in part by a range of public policy interventions including mobilising the integrative power of demand drivers from large scale strategic public procurement, and the **design**, **planning** (link 1) stage of the Smart Building value chain.

The previous section summarised the links in the model of a well-integrated Smart Building value chain, and the relevance of Industry 4.0 technologies to each link.

This section examines the present character and capabilities, and strengths and weaknesses, of each link or stage in Australia's Smart Building sector. The assessments of current capability represent the consensus of opinion from participants in the industry workshops.

To repeat, the first link in the Smart Building value chain is **design**, **planning**. This link establishes the characteristics of the project, helping to determine the nature and level of value chain integration across the project. This illustrates the potential integrative and innovative power of the developer for high-quality outcomes for all project stages and the final product.

Over the past 20 years, use of BIM has been embedded from larger companies through to SMEs. However, there is less diffusion and use DfMA and other high-end tools, whose more advanced purpose is collaboration and real time decision making across the value chain. Although increasingly applied, DfMA is seen as held back by lack of skills within businesses, and by not being required sufficiently by demanding lead customers[34]. Work is also required to ensure BIM and DfMA systems are able to communicate with each other[35].

It is from **design**, **planning** (link 1) and from the **end markets** (link 7) that strong transformation can be driven along the value chain. **Procurement, supply chain** (link 3) is closely related to **design**, **planning** and operationalises link 1 decisions after the materials choices are made (in link 2). The **design**, **planning** (link 1) function for integration across projects can drive greater awareness and adoption of Industry 4.0 and new business models through all stages.

For developers there are relatively low costs in adoption of DfMA. Rather the challenges are organisational and in ensuring adoption downstream, especially in **production** and **assembly** (links 4 and 5).

A focus on link 1, together with **procurement**, **supply chain** (link 3) and **end markets** (link 7) as demand drivers will be critical for a national Smart Building strategy.

Link 2 covers the sourcing of **inputs, raw materials** and **intermediate processes**, such as manufacturing and value adding (e.g., iron ore to steel, to flat products).

The principal inputs are steel, aluminium, concrete and timber.

This link is critically important and will define not only our Smart Building sector, but our future economy and environment.

Australia has world-significant deposits of the majority of minerals required to make these inputs, especially steel and aluminium.

34 Ibid.
35 Ibid.

However, Australia has lost critical manufacturing capacity over recent decades with the move to an economy over-reliant on resource extraction and export of unprocessed raw materials. In 2019 Australia's exports of iron ore accounted for almost half of world supply, but Australia provided less than 0.5 percent of global steel production[36]. Onshore production capacity relevant to link 2 of the Smart Building value chain needs to grow dramatically.

This is coupled to the urgency of decarbonisation, which is driving demand for materials such as responsible steel and aluminium. The unavoidable low carbon transition poses costs, but there are large net benefits to the Australian economy from this transition.

Australia has world-significant endowments of renewable energy sources, which can be the fulcrum for Australia's reindustrialisation: because renewable energy (unlike coal) is hard to transport, the world's requirements for energy-intensive materials such as these will increasingly be met through onshore production close to the renewable energy source. This is favourable to the transformation of Australia's construction industry to Smart Building, and the basis for a new value adding industry for Australia.

And Australia retains (reduced) production capacity in steel and aluminium, providing a basis for future expansion. The shift from conventional to responsible metals production is a positive gamechanger for Australia and basis for reshoring of production.

Applications of steel to prefabrication include mild and hot rolled steel, and light gauge steel[37]. Aluminium is favoured on account of its light weight, strength, and corrosion resistance. Aluminium applications are primarily frames for window casings, wall panels, roofing solutions and drains. As stated previously, Australia has major bauxite mineral deposits and retains some production capacity but is highly import-dependent for finished conventional aluminium. The move to responsible aluminium favours reshoring of aluminium processing and value adding.

Timber has multiple applications to prefabrication and Smart Building from cross-laminated timbers (CLT) to traditional timber framing to prefinished panels. Indeed, its applications to Smart Building are growing as the technology develops and allows use in larger and taller buildings. Its advantages include being a renewable resource, with a lower carbon footprint than concrete

36 Worrall, L, Gamble, H, Spoehr, J, 2022. The Circular Economy – International Lessons and Directions for Australian Reindustrialisation. Adelaide: Australian Industrial Transformation Institute, Flinders University of South Australia, and Worrall, L, Gamble, H, Spoehr, J & Hordacre A-L. 2021. Australian Sovereign Capability and Supply Chain Resilience – Perspectives and Options. Adelaide: Australian Industrial Transformation Institute, Flinders University of South Australia.
37 PrefabAUS (October 2022), Adoption of Design for Manufacturing Assembly in Prefab Construction.

(a non-renewable resource), due to the facts that that during growth timber absorbs carbon dioxide and has lower energy requirements than concrete in production.

Timber lends itself to prefabrication as a lightweight material that is easy to handle and transport, and easy too to cut, shape and join. Timber components are suited to factory production and subsequent onsite assembly. Timber is suited to the logistic requirements of prefabrication and can be applied to panelised forms, integrated through cassette, advanced docking, and other prefabricated solutions. Through lighter weight, timber can reduce loads on foundations and structures, potentially providing cost savings (as well as carbon savings through reduction of amounts of concrete needed). Good thermal properties also provide longer term carbon and cost savings. Timber's weaknesses relate to fire hazard (if untreated), proneness to moisture and insect damage over time, some susceptibility to warping, shrinkage and expansion, and lower strength compared to its main competitor, concrete.

There is a clear trend to Mass Timber Construction (MTC), that is, use of timber materials with a thickness of 75 mm or more. Cross Laminated Timber (CLT), Glue Laminated Timber (GLT), Nail Laminated Timber (NLT), Dowel Laminated Timber (DLT), and Laminated Veneer Lumber (LVL)) are the most common mass timber construction materials[38]. Their use correlates to increasingly versatile applications of timber and its sustainability benefits.

CLT is growing in importance as a Smart Building material for flooring, façade and walls, as well as for volumetric modules and the entire building. Jayalath et al.[39] showed that a CLT building offers a 30% reduction in life cycle greenhouse gas emissions over a reinforced concrete building in Melbourne.

Although Australia has abundant raw material supply, timber systems are not available at scale, and demand exceeds supply. There is high import dependency in segments such as LVL, and CLT. And although local businesses are building capabilities, European competitors have the upper hand.

With growing interest in mass timber, it is planned that robots will be used to construct a building at Western Australia's Murdoch University. Researchers from the University of Technology, Sydney (UTS) will be developing robots that will fix screws in the proposed 'Building 360'. This will be the world's first project of its kind at Murdoch's South Street campus with the aim of obtaining a 6-star Energy rating. This is a large initiative towards automation and will bring positive impact to the construction industry. Robots coupled with the DfMA approach can significantly improve the construction productivity and quality.

The world concrete market was valued at $617 billion in 2020 and is expected to reach $972 billion by 2030 (CAGR of 4.7% from 2021 to 2030)[40]. The concrete market is divided between ready-mix concrete (mixture of cement, sand,

38 WoodSolutions. Massive timber construction - CLT. 2022 [cited 2022; Available from: https://www.woodsolutions.com.au/publications/massive-timber-construction-clt.

39 Jayalath, A., et al., Life cycle performance of Cross Laminated Timber mid-rise residential buildings in Australia. Energy and Buildings, 2020. 223.

40 Allied Market Research, 2023. Concrete Market, https://www.alliedmarketresearch.com/concrete-market-A12420

water, aggregates, and binding adhesives) and precast prefabricated products and elements that are especially important for Smart Building. Concrete is manufactured in batches at a central plant and transported to the construction site. Key precast products include paving stones and slabs, bricks, AAC blocks, and other manufactured elements such as walls, façades, floors, building blocks, pipe, and other similar products.

The concrete market is segmented into the following categories:

- Concrete type and application: grouped into ready-mix concrete, precast products and precast elements, and classified into reinforced concrete and non-reinforced concrete depending on the application.
- End-user industry: grouped into roads and highways, tunnels, residential buildings, non-residential buildings, dams, power plants, mining and so on.

The global precast concrete market size[41] as approximately USD 96 billion in 2021 with an expected CAGR of 5.5% over the forecast period. The expanding construction industry across major regions is expected to drive the precast market due to increasing investments in infrastructure development. Increasing disposable income levels in both developing and developed countries are expected to boost residential construction.

The demand for precast architectural building components is expected to be driven by precast concrete walls, which offer design flexibility and improve profitability. Rapid urbanisation will result in an increasing number of office buildings, schools, shopping centres, hospitals, apartments and parking garages. Precast concrete is expected to gain high demand in rail applications.

Australia has some local production capacity but is largely dependent on imports from China. Although demand will grow with increased urbanisation, concrete is high in embodied carbon. There is Australian research into lower carbon concrete, as also internationally. In combination with other Smart Building materials, however, the carbon impacts of concrete can be curbed. For example, use of lighter weight materials can reduce the required size for load-bearing concrete foundations.

Production, manufacturing and **assembly** (links 4 and 5) constitute the weakest links in the Smart Building Value Chain. In **production**, **manufacturing** (link 4) we often encounter fragmentation and inadequate scale. Regardless of the existence of many highly competent businesses, the majority in the value chain are, at this point, offsite construction companies in the sense of taking conventional construction offsite. They are yet to use the advantages of offsite production to apply fully, the new digital technologies and business models.

The SMEs that predominate encounter high barriers to the digital adoption that is their condition of entry to Smart Building. Digital take-up is hindered by a combination of risks associated with perceived cost and a range of disadvantages in relation to information, organisational capacity, material and time resources, and technical and non-technical know-how. These factors increase perceived or actual transition costs for the business. Against these factors, Smart Building through digital adoption in fact provides the prospect of stronger margins and cost reductions.

Weakness in Production conditions weakness in **assembly** (link 5), including the capacity to integrate common electronic and information systems. This is dependent on being designed in at the earlier links, but especially on its being translated to competences within production.

Through-life support and systems (link 6) is also undeveloped, for similar reasons.

The weaknesses in Production/manufacturing and Assembly increase risks and difficulties to integrated and interdependent Smart Building projects. The challenge is in part to build

39 Grand View Research, 2023, Precast Concrete Market Size, https://www.grandviewresearch.com/industry-analysis/precast-concrete-market

manufacturing capacity in advance of demand. This requires programs directly aimed at building capability, capacity and digital applications, etc., within the Production and Assembly stages.

Weaknesses at links 4, 5 and 6 can also be addressed by mobilising demand drivers from downstream **end markets** (link 7), as can the upstream **design, planning** (link 1) and **procurement, supply chain** (link 3). Demand drivers can be structured and mobilised to transmit requirements and problems and solutions along the value chain, to deliver positive-sum outcomes – including larger and stronger **production**, **manufacturing**, **assembly** and **through-life support and systems** (links 4, 5 and 6) capacity and capability.

Of especial importance in building scale, capacity and capability is the intentional use of large-scale public procurement. The strategic processes of 'advanced' or 'innovation' procurement can use demand as a lever to shape markets towards goals from industrial development, to better climate performance, to affordability and more inclusive communities.

A strong value chain requires strong demand side signals provided by a demanding lead customer(s). These provide an information relay and feedback loop into the supply side. This helps create a virtuous cycle in which problems and issues can be resolved through iterative processes. Markets can be shaped and given positive direction through purposeful public procurement, innovation-friendly industry regulations and standards, and long-term relationships between the industry and finance sector.

These levers – especially advanced procurement used for strategic ends - are underdeveloped in Australia. But their application would provide powerful demand drivers for change in upstream parts of the value chain, especially in production and assembly.

Again, across all stages of the Smart Building value chain, **the integrative power of digital technologies** is critical. These are underdeveloped in Australia.

Table 2: The Smart Building Value Chain: Australia today

Link 1 of the Value Chain	**Design, planning**
Description	DfMA; R&D; problem solving/mgt.; Optimisation; Product testing/ certification; Choice of Materials; Planning
Current Assessment:	LOW-MEDIUM CAPABILITY • Key integrative role of design; establishes key project parameters and requirements. • Critical role of developer across value chain. • BIM well adopted, but more comprehensive DfMA less so. • Limited market intelligence on new opportunities. • Poor digital integration across value chain - organisational challenge. • Most of the required business processes can be developed at reasonable cost and promoted through enterprise education.
Link 2 of the Value Chain	**Inputs, intermediate processes**
Description	Raw materials, value adding, processing and manufacturing: Steel, Aluminium, Timber and Concrete
Current Assessment:	LOW CURRENT CAPABILITY, MAJOR OPPORTUNITY • Abundant raw materials but low capacity for value adding (e.g., responsible steel, aluminium). • Decarbonisation - massive opportunity for secondary processing and reshoring. • Opportunity to build integrated value chain from raw materials. • Timber has major growth potential.
Link 3 of the Value Chain	**Procurement, supply chain**
Description	Supply chain mgt. and logistics; logistics tracking; quality control & product specifications; Materials control

Current Assessment:

LOW-MEDIUM CAPABILITY

- Similar to **design**, **planning** (link 1): digital integration across value chain.
- Relatively low barriers to acquiring the required capabilities.
- But requires scale.
- Enterprise education can help acquire DfMA capabilities.
- Downstream weaknesses, especially production and manufacturing; organisational challenge..

Link 4 of the Value Chain — Production, manufacturing

Description

Production methods; Controls, optimisation and automation; quality control; resource efficiency

Current Assessment:

LOW CAPABILITY, HIGH NEED

- High fragmentation, lack of scale.
- Offsite, not Smart Building.
- Costs of digital falling but high information asymmetries and barriers to entry/adoption.
- High deficits – Industry 4.0, Business Model Innovation, supply chain, workforce skills critical.
- Transition issues from on- to offsite, but potential good margins and cost reductions.
- Stronger demand drivers and program support for digital uptake critical.
- Strong catch-up effort required.

Link 5 of the Value Chain — Assembly

Description

Assembly; systems integration; Electronics; IT; Energy systems; ageing and assistive technologies

Current Assessment:

LOW CAPABILITY, HIGH NEED

- Weaknesses carry-over from Production.
- Higher entry/adoption barriers than for Design & Procurement.
- Lack of integration of electronic and information systems.
- Workforce skills, and stronger demand drivers critical, together with program support for digital uptake.
- Strong catch-up effort required.

Link 6 of the Value Chain — Through-life support and systems

Description

User analytics; Condition monitoring; Predictive maintenance; System upgrades; Energy systems

Current Assessment:

LOW CAPABILITY, HIGH NEED

- Weaknesses carry-over from production, ensuring weakness in making (digital) products for through-life support.
- High import dependence.
- Strong catch-up effort required.

Link 7 of the Value Chain — End markets, design thinking, social-economic purpose, demand drivers

Description

Public procurement; industrial policies; regulation; Industry standards; financial sector norms and practices; capacity for positive market shaping

Current Assessment:

MEDIUM CAPABILITY, MAJOR OPPORTUNITY

- Australia lags in strategic, advanced procurement policy, but emerging focus
- State policies, (e.g., Victorian targets), NRF
- 1.2 million new homes policy
- Better Commonwealth-state dovetailing/coordination.
- Procurement mandating prefabricated content, to drive scale and transformation through value chain, especially production and assembly
- Role of advanced, demanding lead customer is critical for whole value chain
- Better, more consistent regulation and standards.

10. Trends, barriers, scale and proximity to the opportunities

This section isolates trends, barriers (such as minimum scale for efficient production), and opportunities pertinent to each link of Smart Building, together with detail on existing companies and capabilities. It also assesses the urgency of these issues (timescales), together with Australia's proximity to the opportunities and challenges (requisite industrial capability). These factors frame this Roadmap.

The important demand side drivers for Smart Building are:

- Affordability
- Productivity
- Resource efficiency
- Reduced embodied and emitted carbon
- The needs of an ageing population
- Achievement of scale.

Throughout, the importance of achieving project scale is emphasised. Now is the time to clarify a distinction concerning scale vital to the discussion and understanding of desired future development.

Realising the range of Smart Building benefits requires that projects be of substantial scale to allow repeatability and mass customisation, as outlined above. This is distinct from consideration of scale as a barrier to entry in the individual value chain links. In general barriers to entry are not prohibitive, and in the case of **production**, **manufacturing** (link 4), digital technologies now mean that being small need no longer be a disadvantage, and that individual enterprises can be competitive at small-medium scale.

The key is to specialise within a well-coordinated value chain, and to be capable, flexible and efficient within that specialisation.

From the viewpoint of achieving overall project scale, the link 7 demand drivers and public procurement are decisive. From the viewpoint of individual value chain links, high scale is critical for link 2, Inputs, intermediate goods, where the capital-intensive character of steel, aluminium and concrete production establish high barriers to entry and the criticality of long continuous production runs (although this is far less true for timber).

Design, **planning** (link 1) can drive value chain integration, including stronger partnerships with the financial sector. Workshop participants assessed capabilities here as low-medium. Nevertheless, substantial capability exists, and this stage can be well prepared for impending growth. Efficient business operations can be achieved at various scales. Although the imperative is near in time, there is adequate capability for further development.

In supply of **key inputs** (link 2), Australia should commence production of responsible steel and aluminium this decade. Australia should aim to achieve self-sufficiency in, and become a net exporter of, responsible steel and aluminium and other basic metals using energy-intensive carbon-free production over a longer time frame[42].

High minimum efficient scale applies. The need is urgent, with major investment required and expected.

Timber presents a high opportunity near in time, but with major industry development challenges. Without addressing these, imports would meet the rising demand. Unlike steel and aluminium,

42 Worrall, L., Gamble, H, Spoehr, J, 2022. The Circular Economy – International Lessons and Directions for Australian Reindustrialisation. Adelaide: Australian Industrial Transformation Institute, Flinders University of South Australia. See also, Garnaut, R., Super-Power: Australia's low-carbon opportunity, 2019.

high economies of scale are far less an issue than industry fragmentation, requiring dedicated program focus. The requirement and opportunity are near in time and, although challenging, can be met through program effort.

Concrete remains a critical Smart Building material, despite its high carbon content. In combination with lighter materials, the requirement for concrete in foundations can be reduced. Although there is local production, Australia is very import-dependent. However, this is not a significant impediment to Australia's adoption of Smart Building.

Link 3, **procurement**, **supply chain** operationalises decisions locked in at link 1, and shares with it a low-medium capability designation from the industry workshops. Nevertheless, Australia does have pockets of substantial capability and can be well prepared for impending growth. Efficient business operations can be achieved at various scales. Like link 1, the requirement is urgent, but there is adequate capability for further development.

In **production**, **manufacturing** (link 4), and **assembly** (link 5), Industry 4.0 has likely lowered actual costs of entry, and adoption of relevant new technologies. This has made production at small and medium scale feasible, but informational and organisational barriers to adoption are high. The sector's fragmentation exacerbates this. A large jump is required to bring these components up to required capacity and capability in the short time available to meet rising demand. The requirement for industrial capability and capacity is urgent (near) but the gap is large. Capacity and capability need to be developed in advance of demand.

Through-life support and systems (link 6) is a relatively small market with large growth potential. Much of this demand is likely to be captured by imports. Australia's weakness here is conditioned by overall weakness in production, but there is potential in low-cost sensor technologies and systems integration. With large scale projects in prospect, local producers should seek a competitive foothold within their integrated electronic systems, rather than see these given over to imports entirely. The opportunity and requirement are urgent (near). Local capability and capacity can grow and compete with imported items.

End markets (link 7), is critical. A purposefully organised system of advanced public procurement brings the essential scale, coordination and alignment along all the links. It acts deliberately as a demanding lead customer to achieve higher capability and new products, processes and services across the value chain. Generally speaking, Australia trails other advanced economies in effective deployment of demand side drivers such as public procurement and needs to develop the systems and expertise to apply these powerful drivers. The opportunity and requirement are urgent (near), but the capability and capacity of national, state and municipal authorities can grow in coordinated response to the growing need.

Table 3: The Smart Building Value Chain: issues and prospects

Link 1 of the Value Chain - Design, planning

Trends	DfMA; supply chain integration; digital.
Barriers	Low barriers to adoption of DfMA & digital; substantial existing players; openings for newcomers. Integration challenge integration across value chain. Build DfMA skills across industry – education program.
Opportunities	Use to drive integration across value chain, including with finance sector. Greater requirement for DfMA from end markets can drive major acceleration and improvement across the sector.
Import competition	Not significant.
Aust. Companies/ authorities	Green Timber Technology, Hickory, PT Blink, Schiavello, Viridi Group, XLam.
Capability & capacity gap	Low-Medium.
Opportunity/challenge near or far?	Very near.

Link 2 of the Value Chain - Inputs, intermediate processes

Trends	**Steel and aluminium** - Responsible steel and aluminium certification, publishing of open and transparent Environmental Product Declarations (EPDs) and use of rating tools such as Good Environmental Choice Australia (GECA). **Timber** - Low carbon material. Abundant resource. Growing application to larger, taller buildings through CLT. **Concrete** - High in carbon, but an important Smart Building material.
Barriers	**Steel and aluminium** - Entry barriers very high, but Aust has existing capacity, capable of expansion. Very high minimum efficient scale; dominated by large companies. **Timber** - Economies of scale less of a challenge - industry fragmentation is. **Concrete** - Capital-intensive; high barriers to entry.
Opportunities	**Steel and aluminium** - Value adding for green needs to be close to green power source. **Timber** - Value adding, low carbon industry. Can be achieved through coordinated policy effort. **Concrete** - Increasing use in combination with lighter materials such as timber.
Import competition	**Steel and aluminium** - Current high import dependency for conventional steel and aluminium. China the main source of Aust imports. Move to Responsible Steel away from conventional is game-changing: means more onshore production/higher self-sufficiency. **Timber** - Current high import dependency, despite natural resource base. Expanded demand could leak to imports unless local policy is reconsidered so capability and capacity grows. **Concrete** - High imports from China particularly.
Aust. Companies/ authorities	**Steel and aluminium** - Aust. Has two steelmakers: BlueScope, Liberty Steel. Aluminium: Alcoa, Boral, Rio Tinto, Tomago. **Timber** - CUSP, XLam. **Concrete** - Adelaide Brighton, Austral Bricks, Boral, Brickworks, CSR Limited, James Hardie.
Capability & capacity gap	**Steel and aluminium** - High, but concerted effort underway. **Timber** - Significant, but strong potential. **Concrete** - Current low capacity, but not viewed as a significant overall impediment. Low-Medium.
Opportunity/challenge near or far?	**Steel and aluminium** - Very near, expansion of responsible steel and aluminium this decade. **Timber** - Near, but major effort needed to lift capability. **Concrete** - Will remain an important prefabrication material. Lower carbon concrete is a large area of research. Future use is increasingly in combination with other, low carbon, materials.

Link 3 of the Value Chain - Procurement, supply chain

Trends	Digitalisation; new business models.
Barriers	Similar to **design**, **planning** (link 1), including digital integration challenge across value chain.
Opportunities	Relatively low barriers to acquiring the required capabilities. But needs project scale. Enterprise education can help acquire DfMA and other capabilities.
Import competition	Not significant.
Aust. Companies/ authorities	Green Timber Technology, Hickory, PT Blink, Schiavello, Viridi Group, XLam.
Capability & capacity gap	Low-Medium.
Opportunity/challenge near or far?	Very near.

Link 4 of the Value Chain - Production, manufacturing

Trends	Industry 4.0; climate, affordability, ageing in place, new business models.
Barriers	Fragmented. Insufficient capacity for prospective demand; unprepared. 'Offsite' in physical sense, not yet taking on expansive potential of Industry 4.0. Costs of digital technologies falling, but informational and other barriers to digital adop-tion.
Opportunities	Minimum efficient scale falling, due to digital tech., but large informational and organisational impediments. Scale critical at project level. But digital means that production can be competitive at lower scale.
Import competition	Low import competition at present, due to overall market immaturity. Imports could capture market when demand increases.
Aust. Companies/ authorities	ATCO, Ausco Modular, Centina Modular, Dynamic Steel Frame, EZSTEEL, Fleetwood Australia, Hickory, HOMAG Australia, Modscape, Prebuilt, Schiavello, Speedpanel, Timber Building Systems, XLam.
Capability & capacity gap	Large capability and capacity gap. Major jump needed.
Opportunity/challenge near or far?	Timewise, urgent (near). Strong catch-up effort required.

Link 5 of the Value Chain - Assembly

Trends	Same as for Production, manufacturing. Weaknesses carry over from Production, manufacturing.
Barriers	Scale is less important, but informational and other barriers. Lack of integration of electronic and information systems. Lack of strong demand drivers.
Opportunities	Workforce skills critical. As for Production, manufacturing. Low import penetration, but due to overall low market maturity.
Import competition	Imports could capture market share when demand increases.
Aust. Companies/ authorities	Some degree of natural protection. ATCO, Ausco Modular, Centina Modular, Dynamic Steel Frame, EZSTEEL, Fleetwood Australia, Hickory, HOMAG Australia, Modscape, Prebuilt, Schiavello, Speedpanel, Timber Building Systems, XLam.
Capability & capacity gap	Large capability and capacity gap.
Opportunity/challenge near or far?	Large capability and capacity gap. Major jump needed. Timewise, urgent (near). Strong catch-up effort required.

Link 6 of the Value Chain - Through-life support and systems

Trends	Increased automation of homes and buildings for performance (energy, climate, welfare of elderly, etc).
Barriers	Weakness in production ensures weakness in making (digital) products for through-life support. But barriers to entry are not necessarily high.
Opportunities	Australia is a low adopter; major growth potential.
Import competition	Likely high import dependency but ability to acquire/adapt capabilities in low-cost sensor technologies and systems integration.
Aust. Companies/ authorities	Australia has a range of competent digital technology, systems integration and energy management businesses that could be oriented toward expanding the Smart Building sector. Barriers to entry are not prohibitive. They include APS Industrial, Automated Solutions Australia, Entech Electronics, Hetech, Home Automation Melbourne, Omron Electronics, SAGE Automation, Schneider Electric, Siemens, Technology One Australia, and others.
Capability & capacity gap	Large capability and capacity gap, but opportunities apparently within reach.
Opportunity/challenge near or far?	Quite near in time; large jump in capability required, but possible. Strong catch-up effort required. With largescale projects in prospect, local producers should seek a competitive foothold within the integrated systems embedded in these projects.

Link 7 of the Value Chain - End markets, design thinking, social-economic purpose, demand drivers

Trends	Large scale public procurement. Regulation and standards as market shapers and innovation drivers.
Barriers	Policy underused in shaping demand. Capability gaps in public agencies.
Opportunities	Use procurement to drive demand and innovation along the value chain.
Import competition	Not applicable.
Aust. Companies/ authorities	NRF, NHA, HAFF, NHIF, BCA, NCA State, Local and Commonwealth governments.
Capability & capacity gap	Major policy and coordination issues, but capabilities can be acquired quickly.
Opportunity/challenge near or far?	Near, urgent. Capabilities can be acquired quickly.

11. The Australian Prefabrication Roadmap 2023-2033

Our Vision, Our Objectives: 2023-2033

Over the coming decade, we will aim for an Australian Smart Building industry of growing size and significance that helps all citizens achieve secure, quality, affordable housing, while increasingly servicing middle market demands for diverse options and additional amenity.

An industry providing benefits of higher productivity, speed and quality to Australians' housing needs, as well as to essential public infrastructure and services (health and education facilities), and to the needs of the industrial, logistical and commercial sectors.

An industry that contributes significantly to Australia's environmental and climate goals, through buildings with dramatically lower embodied carbon, higher resource efficiency in production, superior design, and greater energy and water efficiency over their entire lives. A Smart Building sector aligned to an ageing population remaining in their homes in comfort, security and in inclusive communities.

An industry that responds to the need of the Australian economy for greater diversity and new knowledge intensive industries, incorporating digital manufacturing technologies and new business models into construction, to supply the Australian community with attractive, quality multipurpose buildings, with high functionality and amenity.

A building sector that is smart not only because it uses smart technologies and methods in production, but also smart digital technologies enabling buildings to perform to high standards of energy and resource efficiency throughout their lives.

By 2033 a series of successful Smart Building projects has transformed public perception and confidence to embrace prefabrication as a high-quality fit for purpose choice – a value proposition of superior quality, cost- and time-advantages.

By 2033 the sector forms a coherent and highly capable value chain embedding integrative digital technologies from upstream (DfMA) to production and assembly, using low carbon materials and technologies to provide high climate-performance design and through-life performance. Smart Building is a leader of Australian industry's decarbonisation push, together with showing the way to greater affordability and inclusive communities.

The questions for us in 2023 are: what time-bound targets should we adopt, and what are the levers we should deploy to achieve them? Where do we want to be, and how do we get there? How will Australia's Smart Building sector of 2033 differ from today?

Smart Building Targets 2023-2033

Australia's Smart Building Revolution will see transformation of the sector over the decade to 2033. Our ambitious targets reflect this major change. These targets can be achieved through the recommended actions. The targets reveal the immense benefits that prefabrication and Smart Building can deliver to Australia's economy, society and environment, through focus, planning, strong partnerships, and strategy and policy.

T1	Sector growth	Smart Building growing from 15% of total construction sector in 2025 to 30 percent in 2033.
T2	Sector growth	Prefabrication provides the majority of public sector construction by 2033.
T3	Production, manufacturing	80 percent of building elements (facades, structures, wet areas and services) are manufactured off site in smart factories – the preferred construction methodology for the built environment.
T4	Affordability (production)	Through achievement of scale (30 percent of total construction and the majority of public sector construction by 2033, as well as providing 50 percent of the 2030 NHA build), deliver savings in production of 20 percent.
T5	Affordability (through-life)	By 2033 demonstrate a minimum 20 percent prefabrication life cycle cost advantage over conventional.
T6	Productivity	By 2033 Smart Building has demonstrated a 20 percent cost advantage over conventional construction.
T7	Productivity	By 2033 Smart Building has demonstrated a home construction time advantage of 12 weeks over 12 months for a conventional build.
T8	Resource efficiency	By 2033 Smart Building has demonstrated a 50 - 80 percent reduction in waste on the way to net zero and UN Sustainable Development Goals.
T8	Carbon reduction (production, embodied)	By 2033 Smart Building has demonstrated a 50 - 80 percent reduction in embodied carbon on the way to net zero and UN Sustainable Development Goals.
T 9	Carbon reduction (Responsible steel)	By 2033 agreed levels of responsible steel content mandated for all major public and private sector projects.
T10	Carbon reduction (through-life energy efficiency)	By 2030 commence production of 10-star energy rated buildings and homes.
T11	Towards carbon neutrality - DfMA	Mandated use of DfMA in all public and private sector major projects to provide digital truth and tools to confirm use of low carbon materials and methods, together with low carbon through-life performance.
T12	Digitalisation and Design for Manufacturing & Assembly	By 2030 DfMA is mandated to achieve digital integration and DfMA for all major public and private projects - automated design, AI - the industry standard leading to increased delivery innovation and continuous improvement.

T13	Circular Economy	Consistent with a 50 – 80 percent reduction in waste by 2033, have a recognised comprehensive national policy for the Circular Economy in construction, including targets for: • Use of recycled materials in new buildings • Standards for the minimum operational efficiency and life of specific products and modules and pods, and for their end-of-life reuse or recycling • End-of-life disassembly of a building or structure, and recycling, reuse, or repurposing of key components and materials.
T14	Inclusive workforce	Our industry is a preferred employer for diversity, equity, inclusion and being women-friendly.
T15	Strategic public procurement favours Smart Building	Starting with the NHA and the 1.2 million new homes aspirational goal, prefabrication and Smart Building provide the majority of all public sector construction by 2033.
T16	National Housing Accord (NHA)	By the final NHA year (2030) prefabrication and Smart Building account for at least 50 percent of the 2030 build.
T17	Other major projects	Australian prefabrication supplies 50 percent of the build for the $2 billion package announced at the cancellation of the Melbourne Commonwealth Games (sporting infrastructure and regional housing). Australian prefabrication supplies 80 percent of the build for the 2032 Queensland Olympic Games athletes' village. DFAT mandates use of Australian prefab solutions for the replacement of the Pacific Islands assets as well as critical consular and diplomatic facilities. Recognising the security advantages of offsite construction, Australian prefabrication supplies the majority of the construction requirements of the Australian Defence Forces throughout the decade.
T18	Business creation	By 2033 treble the number of businesses in the Smart Building value chain and achieving Smart Building accreditation, against 2023-4 baselines and benchmarks.
T19	Changing shape of the market	Against benchmarks established by earlier biennial surveys of major companies, governments and home buyers, by 2033 majority acceptance has been achieved in each market segment concerning the superiority of Smart Building over conventional construction.

Australia's Smart Building sector: Recommended Actions

Key actions are required to realise Australia's $9 billion Smart Building opportunity. The actions must align well to the critical challenges, opportunities and priorities of developing Australia's prefabrication sector. Note that the order of presentation of actions and recommendations below does not imply chronological priority: action on all these fronts must commence soon.

1. Recognise the Importance of Smart Building in Government Industrial Policies

- Australia lacks comprehensive policies to support the Smart Building revolution. But there are significant recent policy changes in favour of the nation's reindustrialisation.
- Australia has a range of important initiatives supporting prefabrication and Smart Building, from state governments to university-based research bodies, aimed at developing future industry directions. But they do not constitute a national policy.

Embed Prefabrication and Smart Building in National Policies and Programs

Nationally there is new recognition of the imperative of Australian reindustrialisation, principally through the NRF, which has various touchpoints to prefabrication, and growing recognition too of the prefabrication sector's potential not only as a source of new industrial growth, but also as an aid in addressing a range of society wide challenges. The commitment to build 1.2 million new homes also presents opportunities to apply industrial methods and solutions at scale.

Elevate recognition of prefabrication and Smart Building in policy and programs by:

- Embedding Smart Building goals in existing national initiatives, especially the NRF and the NHA 1.2 million new homes initiative.
- Recognising explicitly prefabrication and Smart Building as a policy and program focus for a national integrated industrial policy approach and mission.
- Maximising coordination and forward planning between Commonwealth, state and local governments, the whole industry (developers, financiers, designers, manufacturers, assemblers, etc.), and trade unions, to build scale and set directions favourable to the development of prefabrication and Smart Building.
- Commencing development of industry performance baselines and metrics (cost and time savings over conventional, superior climate performance, etc.) to provide evidence and support for the society-wide changes urgently needed.
- Commencing identification of 10 exemplar Smart Building Flagships that will become demonstrators of the benefits of prefabrication.
- Creating a national mission for Smart Building, including explicit recognition of its connections to larger societal objectives of reindustrialisation, decarbonisation, and affordability and social inclusion.

Impact and Benefits

- High impact. Critical to unlocking the full range of Smart Building benefits, including $9 billion in annual returns to Australia's economy.

Key Players

- Governments, industry, superannuation funds, financial institutions, developers, trade unions.

2. Build scale: Apply strategic public procurement principles

- Scale and repeatability are required to achieve Smart Building benefits, but much of the sector is fragmented.
- Scale is needed to justify investment across projects, although digital technologies are lowering minimum efficient scale in production and assembly.
- Advanced public procurement can build scale, promote innovation, creation of new products, processes and technologies - builds the local supply chain and helps investment.
- Building scale improves flow of investment funds as confidence grows.
- Procurement as industrial policy is underdone in Australia, but increasingly deployed in Europe and Asia through Green Public Procurement, e.g., Singapore's mandate for prefabricated modules.

Apply strategic public procurement principles

A successful strategy leverages demand side drivers to build scale by applying strategic public procurement principles to selected large scale projects, including: the policy to build 1.2 million new homes, relevant projects attracting public support under the NRF, school and hospital builds, infrastructure for hosted major events (Olympic Games) infrastructure development associated with the future defence expansion, and so on. The aim is to use large scale purchasing to stimulate innovation and the creation of new products, processes and technologies, and geared to resource efficiency, energy efficiency, lower carbon footprint, population ageing, and inclusive affordable housing.

It would involve mandating or at least targeting a specified quantity, quality and character of Smart Building in projects, as practiced in Singapore and latterly, the UK. For example, a certain proportion of 3D bathroom pods or, later in the decade, use of responsible steel.

This could be applied not only to defined projects, but also be made conditional to large scale releases of land to developers.

Strategic procurement is driven by multiple goals beyond delivery of discrete projects at lowest cost, to include a focus on problem-solving, collaboration and innovation all along the value chain, and the possibility of collaborative tendering processes over simple competitive (price-based) tendering. Such processes allow for consideration of whole of life costs and benefits, such as lower through-life energy consumption through smart design and technology. Conventional tendering concentrates on achieving the lowest cost contract, and generally, cannot take account of other strategic factors or aspects of building performance. Conventional procurement aligns to cost – price factors at contract stage; strategic procurement aligns with value-for-money concepts taking in wider concerns.

Properly targeted and structured, these public procurement policies would help to develop a competent integrated value chain, and improvement and increased capacity in current areas of weakness, particularly Production, manufacturing and Assembly. They thereby would help to overcome other problems, like the reticence of lenders.

The concept also includes maximum coordination and dovetailing of Commonwealth, State and Local government projects of significant scale and size, as well as large private sector projects in receipt of public financial support. The objective is to build project scale with visibility and capacity for forward planning by industry, as well as to provide flagship projects demonstrating superior Smart Building performance against clear baselines and metrics.

To the maximum possible, it would take a portfolio approach, providing industry with prospective information on the totality of actual and possible major projects on a 3-, 5- and 10-year rolling basis.

It is recognised that the required organisational capabilities and systematic maturity can only be developed in a progressive and staged manner. This requires public agencies to target projects that offer large and timely returns and that can function as demonstrations and flagship projects. The ability to solicit and assess bids that consider not just price on completion, but through-life value (encompassing capital cost, maintenance, management, operation, periodic upgrades, and final retirement of the building) is far from a given, and must be developed over time.

Commence development of major coordinated public procurement strategy to build Smart Building scale, with:

- Maximum coordination and dovetailing of Commonwealth, State and Local government projects of significant scale and size, as well as large private sector projects in receipt of public financial support.
- A portfolio approach, where possible providing industry with prospective information on the totality of actual and possible major projects on a 3-, 5- and 10-year rolling basis, to build project scale and visibility and capacity for forward planning by industry.
- A 'Presumption in favour of prefabrication' in selected projects.
- A focus on sectors and projects meeting critical needs and providing exemplars and flagships demonstrating Smart Building performance and benefits.
- Targets or, as appropriate, mandates, in designated major projects (e.g., 1.2 million new homes, Olympic Games works, other) such as minimum level of Smart Building, use of low carbon materials, etc.
- Application of other strategic procurement principles including:
  - Assessing procurement decisions on whole of life costs and lifecycle value rather than price on completion
  - Assessing bids on their use of digital technologies in both production and in through-life operation of the project or building(s)
  - Assessing bids for their innovative content, in production and construction, through-life operation, and in solving site-specific or general challenges such as inclusive communities and low carbon living
  - High use of standardised quality componentry or, especially in the early stages, the development of standardised quality componentry for a given project that could be applied to subsequent projects
  - Using Early Contractor Involvement (ECI) to foster collaboration and align all links of the value chain, and to maximise opportunities for iterative solutions and innovations
  - Preparedness to break down large work packages into smaller ones to help develop, and provide opportunities to, a competent array of tier 2 and tier 3 suppliers.
- Provision of training programs in public sector strategic and advanced procurement.
- Active advanced public procurement shaping the market, resulting in standardised components and systems corresponding to a kit of parts and standardised systems for the full suite of government infrastructure assets[43].

Impact and Benefits

- High impact. Critical to unlocking the full range of Smart Building benefits, including $9 billion returns to Australia's economy. Creates scale as well as new institutional processes as the basis of a virtuous cycle of Smart Building growth and development.

43 Office of Projects Victoria (Treasury and Finance), Offsite Construction Industry Analysis. Digital Build program 2021.

Key Players

- Governments, industry, superannuation funds, retail financial institutions, developers.

3. Position Smart Building within the National Housing Accord (NHA) (1.2 million new homes) and other major projects

- NHA includes all levels of government, investors, and the construction sector to improve supply of affordable housing, with an aspirational target to deliver 1.2 new, well-located homes over the five years from 2024.
- The HAFF and its NHIF will provide financing to affordable housing projects, with high energy efficiency ratings.
- Other forthcoming major projects, such as construction for the Olympic Games, provide opportunity to grow the sector.
- Housing is the construction subsector with the highest growth potential, with positive flow-through benefits to the whole Smart Building sector.

Leverage scale from the 1.2 million new homes target to accelerate Smart Building

The scale and requirements of this program provide major opportunity to accelerate development of a sophisticated and knowledge-intensive Smart Building sector, whose advantages include higher productivity, lower cost and construction periods, and higher energy efficiency. At the same time, a project such as this, dovetailing national, state and local governments, bringing in investors, planners and standards authorities, and investors and superannuation funds, has the potential to create rapid solutions to many barriers the sector faces.

Housing has the highest potential for rapid Australian Smart Building growth. A focus on housing will build Smart Building capacity and capability applicable to all prefabrication subsectors. The housing focus allow greater realisation of prefabrication benefits earlier: higher productivity, affordability, low carbon living, and inclusive and ageing-friendly communities.

Recognising the strong fit of prefabrication and Smart Building with the scale and requirements of the NHA, HAFF and NHIF, together with their bringing together of national, state and local governments, investors, planners and standards authorities, and investors and superannuation funds:

- Set target for prefabrication and Smart Building share of the NHA target such that by its final year (2030) prefabrication and Smart Building account for at least 50 percent of the 2030 build.
- Use the NHA process, involving constructors, standards and accreditation bodies, planners, lending institutions and superannuation funds, to push through current impediments with model arrangements that prove their efficacy and value over time.
- Work to identify prospective supply chain capability requirements in advance to address gaps and weaknesses through industrial programs and policies.

In addition, to further build scale as the foundation for a Smart Building sector, identify other major projects for large scale application of prefabrication, and set prefabrication targets for them:

- Australian prefabrication supplies 50 percent of the build under the $2 billion package announced at the cancellation of the Melbourne Commonwealth Games, being the continuation of the promised new and upgraded sporting infrastructure projects, and the Regional Housing Fund to deliver more than 1300 new homes across the State's regions, including social and affordable housing.
- The 2032 Brisbane Olympics build achieves an 80 percent target for Australian prefabricated content in building and infrastructure.

- DFAT mandates use of Australian prefab solutions for the replacement of the Pacific Islands assets as well as critical consular and diplomatic facilities.
- Recognising the security advantages of offsite construction, Australian prefabrication supplies the majority of the construction requirements of the Australian Defence Forces throughout the decade.

Impact and Benefits

- High impact. Critical to building scale to reap and to demonstrate benefits of Smart Building, and develop broader understanding and acceptance of the advantages of Smart Building.

Key Players

- Governments, industry.

4. Embed Design for Manufacture and Assembly (DfMA) in projects

- DfMA brings standardisation and optimisation to prefabrication, reducing the number of parts and the costs of production
- DfMA is critical to delivering large scale projects and an integrated, capable value chain
- It is critical also to mass customisation and to shifting the popular image of the industry toward higher quality, amenity and performance
- But DfMA capabilities need to be developed within the **design**, **planning** stage (link 1), and then extended throughout the value chain
- Strong value chains need knowledgeable, demanding lead customers that can build scale and make capability improvement happen, especially in the weakest links
- But DfMA is not a mandatory requirement often even in large projects.

DfMA is critical to delivering large scale projects and an integrated, capable value chain, to mass customisation and shifting the popular image of the industry toward higher quality, amenity and performance. DfMA is critical to Smart Building's ability to deliver Circular Economy goals, higher productivity, increased resource efficiency, and greater affordability. DfMA is critical also to realisation of prefabrication benefits of higher productivity, significantly reduced cost and construction times, reduced waste and defect-free production, and delivery of items at fixed prices.

To play this integrative role, capabilities at the **design**, **planning** (link 1) stage need to be augmented, while awareness of DfMA benefits and requirements must be disseminated along the whole value chain. DfMA brings standardisation and optimisation to prefabrication, reducing the number of parts and the costs of production. But DfMA is not a mandatory requirement often even in large projects.

BIM is widely used, and can be the point of entry to larger deployment of DfMA, provided interfaces between them can be improved.

Recognising the essential integrative role of the developer in setting Smart Building project parameters and locking in key decisions at the frontend, enact the recommendations of the report 'Adoption of Design for Manufacture Assembly in Prefab Construction' [44], including:

- Devise a DfMA demonstration and education program targeted to businesses in the **design**, **planning** (link 1) stage of Smart Building.
- Ensure the program helps lift the common understanding – and application - of Smart Building and DfMA practices of all industry players, from financiers to regulators to planners to engineers and architects to manufacturers to developers and end customers.

44 PrefabAUS, October 2022.

- Establish benchmarks for use of DfMA and leverage that increasing use to establish baselines on costs, time, wastage, climate friendliness, and greater circularity.
- Increasingly mandate DfMA for prequalification in major projects.
- Increasingly use DfMA not only to reduce waste, but also to provide digital assurance of the provenance and nature of all materials and inputs used, and of their through-life environmental and climate/carbon performance.
- Develop handbooks and guidelines, and data and benchmarks to communicate DfMA requirements and benefits across the industry.
- Work to improve interfaces between existing BIM and newer DfMA systems.

  An advanced program for embedding DfMA at the **design**, **planning** (link 1) and the **procurement, supply chain** (link 3) stages would complement the effort to build scale through advanced procurement demand forces. Both in turn support improvement and the building of capacity in the **production, manufacturing, assembly** and **through-life support and systems** – links 4, 5 and 6 - of the value chain.

  Impact and Benefits

- High impact. Critical to the value chain integration required for scale, and for the progressively rising demand over the decade, and high continued demand thereafter.

  Key Players

- Governments, industry, education and training.

5. Improve access to capital: Finance

- Financing models favour onsite over offsite
- Affects deposits and progress payments, and overall availability of project finance
- Onsite construction provides progress payments against definite milestones, with greater perceived security to the lender (with land and stage of works recoverable in the event of project failure)
- Offsite less suited to payment against project milestones and a greater proportion of finance is required upfront (with finance concerns about security and recoverability)
- Different jurisdictional requirements and regulations
- Fragmentation of supply chains increases insecurity and financier hesitancy
- But this constraint can ease as the sector grows in competence, through a project pipeline creating scale and high demand (advanced public procurement)
- Smart Building can be made less risky than conventional
- Commonwealth – state – local government coordination and dovetailing needed.

Address barriers to flow of investment capital

Overcoming structural barriers to the financing of Smart Building is critical. Support is needed for dialogue and processes that can give lenders confidence to invest. This includes development of new mortgage products and structures that reduce the risk of noncompletion and advance alternatives to the traditional progress payments system. The UK BOPAS is one model from which Australia can learn. It assists the flow of investment funds by providing an audit and accreditation regime for prefabrication company creditworthiness, product conformity and quality, and assurance of 60-year durability[45].

The Australian application of a similar approach would provide a framework for assessing prefabrication company creditworthiness, product conformity and quality, and development of an online registry to showcase technologies, products, manufacturers and developers[46].

The $10 billion HAFF sets goals for investment in social and affordable housing, and involves dialogue with financiers, superannuation funds and the states. This includes an aspiration to build 1.2 million new homes in the five years from 2024, an investor roundtable, and an accord with the finance sector and the states, together with a National Housing Infrastructure Facility (NHIF). This gives incentive and a potential point of intervention to advance investment flows to Smart Building and a vehicle for ironing out abovementioned structural difficulties and barriers, to provide investor confidence in revenue streams and project pipelines.

Support the aims of the prefabAUS reports 'Financing Innovation for Prefab Construction in Australia' and 'Regulatory barriers associated with prefabricated and modular construction' [47] regarding financing by:

- Leveraging the HAFF and the 1.2 million new homes initiative to achieve model arrangements for financing of Smart Building that will become embedded and serve the sector's long-term growth.

  Impact and Benefits

- High impact. Utilises scale and demand drivers to embed new practices and relationships favourable to Smart Building.

  Key Players

- Governments, industry, superannuation funds, retail financial institutions, developers.

6. Build consistent nationwide standards and better regulation

- Standards and regulations reflect conventional building - the NCC and BCA are oriented to conventional construction, with state variations
- Need for recognised and uniform quality certification and performance standards
- Affects flow and availability of project finance
- Positive consistent regulation, certification and standards can lead and stimulate industry development and growth, and achieve scale
- Standards can reinforce high prefabrication quality, against dominant public perceptions, and help the flow of investment capital to large scale projects
- Consistent regulation and standards can help build in lower lifecycle costs, superior energy efficiency, and flood and fire resilience.

Create consistent nationwide standards and better regulation to set positive directions

The current regulatory framework discourages the scale required for Smart Building, being oriented to conventional onsite building, and being fragmented and procedurally inconsistent as between states. Inconsistency adds to the barriers to proper flow of finance. Yet regulation and standards can set positive directions and frameworks for industry growth. To the maximum possible degree, different state frameworks should be nationally consistent and supportive of the vision for a modern Smart Building sector.

The goal should be regulation and standards that reinforce the image and reality of Smart Building as a preferred option for quality, through-life performance and environmental characteristics.

45 PrefabAUS, Financing Innovation for Prefab Construction in Australia. Final Report, 16/06/22. Funded by AMGC; Partners: University of Melbourne and PrefabAUS.

46 Ibid.

47 Ibid, and HIA, AMGC, Swinburne University of Technology (October 2022), 'Regulatory barriers associated with prefabricated and modular construction', Final Report.

Enact recommendations of 'Regulatory barriers associated with prefabricated and modular construction' [48] to:

- Change planning system requirements in the NCC, the BCA, and state and territory regulations, to standardise definitions of prefabrication
- Modernise building and construction regulations to support use and approval of prefabrication through a set of clear standards for prefabricated construction and products, with associated testing and certification regimes for manufacture and construction
- Define roles and responsibilities along the value chain, including addressing barriers associated with contracts, progress payments, licensing, inspections and insurance
- Use regulation positively to achieve uplift and improve the industry's image.

Additionally, use the HAFF with its mandate to increase the supply of affordable and social housing (1.2 million new homes in the half decade from 2024) to leverage demand for prefabricated housing and accelerate development of consistent new regulations, standards, testing and certification.

Impact and Benefits

- High impact. Helps build scale and overcome fragmentation.

Key Players

- Governments, industry, financiers, developers.

7. Create an Industry 4.0 dedicated sectoral program focussed on production and manufacturing, assembly and, through-life support and systems

- Opportunities from digital include that in production and assembly, being small need no longer be a disadvantage; minimum efficient scale is coming down
- Costs of digital investment are coming down, and can be phased to minimise risk
- But digital adoption is impeded by information asymmetries, misperceptions, low absorptive capability of SMEs especially
- Major catch-up effort focused on digital adoption and scale in **production**, **manufacturing**, **assembly** and **through-life support and systems** (links 4, 5 and 6) through comprehensive industry and enterprise programs.

Production, manufacturing, assembly and **through-life support and systems** (links 4, 5 and 6) are the weakest links within the Smart Building value chain. Often lacking scale and capability, SMEs are all the more reluctant to invest in digital technologies and associated workforce skills that would open up business opportunities and create a more capable onshore value chain.

Digital adoption by SMEs means overcoming or mitigating several structural constraints, difficulties and limitations, including: constraints imposed by small size, information asymmetries, limited absorptive capabilities, and structural deficits, of which lack of awareness, information and knowledge are central. The required approach involves increasing the absorptive capabilities of SMEs, together with their dynamic capability – their ability to shift and reorganise resources and effort to meet new challenges and opportunities.

SMEs are hindered by uncertainty about the perceived costs (organisational disruption, return on investment) and benefits of investment in digital technologies. Effort must address a range of structural and resource limitations, such as the lack of internal resources for research and development, for achieving ISO qualifications, that leadership

48 Ibid.

is often diluted by a business's never-ending operational requirements, the lack of a comprehensive IP policy, the lack of change management approaches, the challenges of developing new business models, etc.

The weaknesses in these links are acute, and the need is large. The time gap for the required uplift is very tight. The capability gaps must be closed by an intensive effort to catch-up.

Devise a national limited-term program to:

- Accelerate digital adoption for Smart Building and strengthen production, **manufacturing, assembly** and **through-life support and systems** (links 4, 5 and 6) to be delivered through the network of future factories recommended below (Industry awareness and market information: Build the ecosystem) and in the Prefab Innovation Hub: Feasibility Study[49].

The program would use the futuremap® digital diagnostic tool to provide rapid orientation for participating businesses and help tailor the most productive pathways for each business.

Focussed on accelerated uptake of digital technologies for Smart Building, together with the development of digital products and services associated with Smart Building, the program(s) would provide enterprise education on the relationship of these technologies to market opportunities, and tackling challenges in the transition to new business and workforce structures.

By lifting awareness and capability it would work alongside and assist other elements of this Roadmap, such as lifting translation of research, boosting the Smart Building ecosystem (including the role of the many 'future factories' distributed around Australia), lifting workforce skills, and building better relationships between the industry and the finance sector.

Impact and Benefits

- Medium impact rising to high impact over the decade. Builds production capabilities indispensable to the Smart Building value chain, and upon which the strategy's success depends.

Key Players

- Governments, industry, trade unions, education and training, future factories.

8. Promote Business Model Innovation for the accelerated development of Smart Building

- Business Model Innovation is a critical component of the transformation of the worldwide manufacturing and construction. Building on the potential of digital technologies, new business models emerge that bundle buildings with services[50].
- Business Model Innovation creates and captures value by innovating in two or more of: products, processes, marketing, or firm organisation. Its value proposition is capturing additional value and competitive advantage – a composite form of innovation at the intersection of these four areas.
- Superior organisation and innovative business models are sources of competitive advantage that are hard for competitors to imitate.
- Business Model Innovation helps lock in customers for the longer term by bundling services of a long-term nature with products – 'servitisation' – and expands the role of new digital technologies from production to new products, creating new sources of business revenue.

Prefabrication is the form of construction which allows the building sector to maximise the use and benefits of digital technologies. Additionally, prefabrication allows full use

49 AMGC (ND) Prefab Innovation Hub: Feasibility Study. Submission to the Department of Industry, Science, Energy and Resources.

50 Evolution of large-scale Industrialisation and Service – Innovation in Japanese Prefabrication Industry, Journal of Construction Innovation: Information, Process, Management, Volume 12Issue 2, Emerald Group Publishing Limited 2012.

of digital technologies to provide important ongoing services to be bundled with the building.

Industry 4.0 is about production guided by digital technologies. Industry 4.0 is also about new products combined with ongoing delivery of a service. Just as sensors are used to optimise and radically reduce waste in production, so too cheap sensors associated with ongoing service provision can lead to new products that can extend markets and add to business revenues and margins.

Prefabrication lends itself to making smart homes and buildings, automated homes and buildings.

Just as sensors monitor the condition and performance of equipment in production, so too can they be designed into monitoring the performance of the completed building, and the health and comfort of its occupants. This is of great importance especially to service provision to an ageing community, and to the building's climate performance and energy efficiency.

Adding services to the products a business makes can be a vast opportunity. This can be done using sensors and cloud-based services.

The business model is reconfigured from a single transaction (sale) of the product repeated as often as possible, with a longer-term relationship between producer and purchaser underpinned by the bundling of services with the product(s). It becomes a product-service model. This may require a business's revenue model to go from profit on sale to revenue extended potentially to the end of the life of the product, or its reuse, remanufacture or recycling. Between production of the product and its end of life, the vendor may have provided condition and real-time performance monitoring, preventative maintenance (using sensors and other digital technologies), and through-life modular equipment upgrades. For both vendor and purchaser, a relatively larger part of the revenue or cost of providing the product comes from the associated services compared to production costs.

Integrate Business Model Innovation into the entire program for Smart Building development by:

- Linking digital adoption sometimes motivated by the prospect of production and efficiency gains only, to changes in business models that enable extension of markets and business revenues, through the development of product-service models (or servitisation) over time.
- Ensuring Business Model Innovation content in the dedicated Industry 4.0 sectoral program, as well as the business advisory and industry development programs delivered through the Prefabrication Innovation Hub ecosystem.
- Ensuring that large scale public procurement concerned with value for money and taking account of lifecycle costs and performance of buildings (not just their production and construction costs), adopts a product-service model where appropriate.

Impact and Benefits

- High impact. Helps to maximise benefits from digital adoption and Smart Building, and returns to society in in lifecycle costs and performance of buildings (climate, inclusiveness, etc.).

Key Players

- Governments, industry, financiers, developers, education and training, future factories, trade unions.

9. Build the future workforce

- Offsite Smart Building applies manufacturing technologies generally and digital especially
- A comprehensive workforce strategy becomes the backbone of a new industry
- Traditional construction trade skills will change; current divisions limit scope for multiskilling and positive career paths

- Offsite provides and more attractive environment for women workers, while younger workers will be attracted by opportunities to apply digital skills
- New skills and pathways, allowing higher skills and career development with transferability (not micro-qualifications)
- Need for prefabrication apprenticeships with digital components and allowing limited electrical and plumbing functions
- A workforce development framework geared to industry growth and more jobs.

Australia's (predominantly conventional) construction sector will be challenged by even larger skills shortages and demographic pressure over the next half decade, with further adverse implications for affordability.

The resumption of immigration and population growth creates additional construction demand against constrained supply. At the same time, nearly 8 percent of the construction workforce exits the industry each year. It is estimated that almost half a million new construction workers will be needed in the five years to November 2026. About half of these will be technicians and skilled trades[51].

Productivity and attraction and retention must become central to a robust workforce strategy, incorporating the growth of Smart Building and its distinct skills requirements.

The future workforce will be the backbone of Australia's 21st Century Smart Building industry. Its development will produce major qualitative changes. Existing trade skills will be supplemented with new capabilities related to manufacturing processes and digital technologies. Some traditionally separate trades will shade into each other at the margins, with a multiskilled production and assembly workforce undertaking certain tasks that were previously only able to be performed by the designated trade.

This should not reduce or deskill functions of existing trades, but allow digitally-enabled workers to perform electrical and plumbing functions to a level required for continuity of production, with ongoing requirement for quality assurance resting with fully-accredited tradespeople.

The changes will make for secure, rewarding career paths and progression. It will create workplaces more attractive to women workers within a growing industry, and younger workers will be attracted by the opportunities to apply digital capabilities. This approach is not about replacing trades and workers, but enhancing their roles and job satisfaction. This framework will support industry growth and more jobs.

Initiate processes and negotiations for a future workforce that will:

- Create opportunities for secure, rewarding career paths and progression.
- Initiate cooperative dialogue and negotiations between unions, industry and training providers, towards a workforce development framework for Smart Building and prefabrication.
- Promote a new trade certificate for prefabrication including digital skills, aimed at enhancing the role of workers and trade skills, not replacing them.
- Collocate TAFEs with future factories and other bodies comprising the Prefabrication Innovation Hub.
- Investigate group apprenticeship arrangements to build scale for the new apprenticeships.
- Promote a schools-based program providing an early pathway into TAFE and Smart Building careers.
- Examine appropriate opportunities for greater credit transfer and recognition of prior learning.

51 Master Builders' Association (April 2023), Future-Proofing Construction: A Workforce Blueprint.

Impact and Benefits

- Medium impact rising to high over the decade. Critical to meeting the demands of a growing, scale-based Smart Building sector and to building a positive industry ecosystem.

Key Players

- Governments, industry, trade unions, education and training.

10. Build the ecosystem: Industry awareness, market information and Smart Building industry clusters:

- Market information is fragmented and needs to be structured to provide an adequate timeframe to industry to prepare for major projects.
- Business extension programs are similarly fragmented.
- Intermediate organisations providing education and information on international market trends, technologies and business models.
- Need to consolidate industry education and awareness raising, together with applied research, into a well-led system of networked future factories, as recommended in the Prefab Innovation Hub: Feasibility Study[52].
- Industry clustering and collaboration can accelerate industry development and growth, and help overcome fragmentation.
- They can accelerate application of new technologies and development of new products and services.

  The accelerated development required of the industry in turn necessitates a knowledge-intensive ecosystem able to supply services critical to that development. These include applied research, technology demonstration and prototyping facilities, information on industry trends, markets and emerging product and service opportunities, workforce development issues, new business models, and so on.

  Ecosystem coordination is especially important in dealing with a fragmented industry structure and businesses – frequently SMEs - that are time- and resource-poor. This ecosystem lowers the time and cost of acquiring critical information, knowledge and capability for individual businesses and the industry.

  These services can be provided through a hub and spoke model, with the advantage that many of the spokes already exist as factories of the future, often already have specific Smart Building facilities and competences, and can form a national network in which each can play to its key strengths. Specialisation within a network of this kind helps ensure high performance. There is a need for coordination and leadership across the sites and system.

  Furthermore, industry clusters provide a framework for regional and nationwide industry collaboration around common needs and challenges, balancing the inherent competitive tendencies with incentives to collaborate to build strong long-term competitive advantage and smart specialisation. Knowledge is shared and common directions agreed. Clusters find points of focus and problem-solving for effective collaboration, and are supported by positive ecosystems and networks of future factories.

Enact recommendations of Prefab Innovation Hub: Feasibility Study[53] to:

- Establish a Smart Building network of business and industry development service providers from existing future factories to form a national Prefab Innovation Hub, as ecosystem coordinators and service deliverers.

52 AMGC (ND) Prefab Innovation Hub: Feasibility Study. Submission to the Department of Industry, Science, Energy and Resources.

53 Ibid.

  - Each future factory would deliver a combination of general Smart Building services while also playing to key specialisations to develop an agile and expert national system.
  - Each future factory would be encouraged to collocate with relevant TAFE facilities to maximise integration with workforce development, and to make use of entry-level diagnostic tools such as futuremap®.
- Promote industry clusters as focal points for the accelerated development of the Smart Building sector, including:
  - Convening an annual Smart Building Industry Forum under the auspice of prefabAUS to progress industry development, report industry baselines and developments against the targets and recommendations of this Roadmap, and its 3-, 5- and 10-year milestones.
  - Establishing baselines and data on Smart Building businesses for annual review and as means of measuring qualitative industry development and quantitative industry growth. Developing frameworks and criteria for prequalification, registration and accreditation of businesses as Smart Builders, taking account of such existing frameworks as the UK BOPAS.
  - Providing handbooks and guidelines for companies developing as Smart Building businesses.

Impact and Benefits

- Medium impact rising to high over the decade. The Prefabrication Hub would provide a vital durable, recognised framework for accelerated learning and capability development, while industry clusters help overcome industry fragmentation and establish baselines and frameworks essential to the strategy.

Key Players

- Industry, Governments, trade unions, education and training, future factories.

11. Create flagships, baselines and benchmarks

- The affordability crisis is evident everywhere one looks
- Problems of structure and low productivity are evident
- Shifting this means leveraging metrics and benchmarks to make the case for a new strategy.

  We can build the future we want not when we assert the advantages and imperatives of Smart Building, but when we demonstrate them to decisionmakers and to the Australian community. This means having flagship projects, such as the NHA 1.2 million new homes objective, that provide demonstrators linked to clear metrics and baselines (where we are now) and benchmarks and targets (where we want to be).

  Demonstrator projects help build quantifiable value propositions for Australia's Smart Building revolution, shifting decisions in favour of through-life value rather than simply cost. At the same time, these can change the return on investment (ROI) equations for major procurers, especially governments, thereby accelerating the desirable transformation.

  The confidence to invest, the desire to purchase, the ability of governments to take decisions to set directions (and achieve an acceptable return on investment), all depend on demonstrated advantages of Smart Building over conventional. That requires demonstration projects providing baselines and benchmarks related to defined targets of a strategy.

  For the public sector especially, the ability to use common metrics, baselines and benchmarks to make comparisons is critical to the ability to make credible decisions based on performance and through-life affordability.

Leverage data and baselines, and utilise flagship projects and targets and benchmarks to provide objective

information in favour of the Smart Building revolution by:

- Designating 10 flagship Smart Building projects (inclusive of the NHA 1.2 million new homes target) as national demonstration projects
- Determining current baselines and performance goals against the targets enunciated in this Roadmap, including demonstrating:
  - A 20 percent cost advantage over conventional
  - A home construction time advantage of 12 weeks over 12 months for a conventional build
  - A 50-80 percent reduction in waste (resource efficiency)
  - A 50-80 percent reduction in embodied carbon
  - Through-life carbon and energy benefits including 10-star energy ratings.

Impact and Benefit

- Medium impact rising to high impact over the decade. Concretely demonstrating Smart Building advantages against consistent baselines and benchmarks provides the bedrock for growing confidence of governments, the industry, wider business and the public.

Key Players

- Governments, industry, education and training, future factories.

12. Shift the image: From prefabrication to Smart Building

- Popular views of the industry are generally negative, unaware of the sector's potential to deliver higher outcomes, individually and across society and the environment.
- As the Roadmap progressively demonstrates gains, and the applications of Smart Building become more embedded, large scale lead customers and individual customers alike will prefer and demand prefabrication and Smart Building.
- 10 major flagship projects will demonstrate the superiority and advantages of Smart Building against clear benchmarks and metrics.
- Smart Building will be synonymous with quality, through-life high-performance, sustainability and affordability and inclusion.

The combined changes wrought by the above recommendations and actions will bring about a changed perception of offsite construction: from prefabrication to Smart Building. Currently prefabrication is associated with firstly, production offsite mostly using onsite processes and yet to embrace the full potential of digital technologies and, secondly with cost-sensitive and basic products in the marketplace.

As trends make themselves felt over time, and as the industry repositions, large scale procurement and individual consumers will demand that prefabrication become Smart Building. This means demand not only for affordability, but also for lower embodied carbon and higher ongoing energy efficiency, and communities that are inclusive of all and ageing-appropriate.

This signifies a changing customer profile and a reorientation toward a quality market midpoint, rather than the low end.

The industry and governments should accelerate the required change by:

- Supporting and promoting exemplar projects to demonstrate Smart Building benefits and advantages – 10 flagships.
- As confidence and trust builds between developers, regulators, finance and investor bodies, and across the value chain, considering regulation and standards that institutionalise competitive advantage for prefabrication and Smart Building, and the use of regulation and certification regimes that operate as positive market shapers, such as:
  - Guaranteed climate performance standards (10-star energy rating)
  - A locked-in 60-year design life reflected in conditions of project funding, investor returns and customer/purchaser guarantees.
- Giving incentive to large scale Smart Building through streamlined planning and approvals processes.

Impact and Benefits

- Impact grows from today's low base to high by the end of the decade. The enhanced image relies upon, and is a consequence of, the prior recommended actions. Over time, however, the newer more positive image feeds a virtuous cycle in which concrete positive demonstrations of transformation raise public expectations, and in which rising expectations in turn contribute to further industry innovation.

Key Players

- Governments, industry, education and training.

2023-2033: How Prefabrication Became Australia's Smart Building

Market growth challenge

Now	Smart Building on way to 15 percent of total construction by 2025.
3 Years (2026)	Growing demand increasingly shaped by procurement focussed on major projects (e.g., Olympics) and affordable housing (1.2 million new homes).
5 Years (2028)	Demand is increasing. Growing consumer awareness of Smart Building benefits results in balanced growth focussed on both affordability and middle market. Perceptions shifting from 'prefab' to Smart Building, and its multiple benefits. Increasing association with high quality. Strategic public procurement now favours Smart Building: Starting with the housing accord and the 1.2 million new homes (and other) commitments. Smart Building is on the way to providing the majority of all public sector construction by 2033, and accounting for at least 50 percent of the 2030 NHA build.
10 Years (2033)	On a strong growth trajectory, with Smart Building now 30 percent of total construction. Shaped by public procurement alongside growing public preference/demand for Smart Building benefits: high quality, lower carbon, through-life efficiency, ageing appropriateness, etc. Smart Building now provides the majority of all public sector construction.

Affordability challenge

Now	Housing affordability is at its worst in Australian history. Productivity improvement through Smart Building can contribute to the solution.
3 Years (2026)	Smart Building has recognition and a foothold in large scale affordability public projects, especially the NHA. Additional capacity and capability have also been created through a strategic approach to the building program announced at the Commonwealth Games cancellation, while the sector starts tooling up for the Olympic Games.
5 Years (2028)	Selected flagship projects (NHA, large public events) are already demonstrating a 20 percent Smart Building cost advantage over conventional. Prefabrication is favoured explicitly for affordable housing.
10 Years (2033)	Through achievement of scale (30 percent of total construction and most public sector construction by 2033, as well as providing 50 percent of the 2030 NHA build), Smart Building is delivering ongoing savings in production of 20 percent. Smart Building is providing the majority of affordable housing.

Productivity challenge

Now	Conventional construction lags and high productivity Smart Building underdeveloped.
3 Years (2026)	Key early projects demonstrate potential for reduced cost and time compared to conventional construction benchmarks.
5 Years (2028)	Cost- and time- benefits now established.
10 Years (2033)	Smart Building has demonstrated a 20 percent cost advantage over conventional construction. Smart Building has demonstrated a home construction time advantage of 12 weeks over 12 months for a conventional build.

Resource and energy efficiency (production) challenge

Now	Conventional high on waste; more resource efficient prefabrication/Smart Building underdeveloped. Conventional building high wastage rates, adding to carbon.
3 Years (2026)	Growing awareness of prefabrication's higher resource efficiency, and connection to lower cost and affordability. Key early projects demonstrate reduced waste and higher resource efficiency compared to conventional construction benchmarks.
5 Years (2028)	Resource efficiency benefits now established. Use of recycled materials is growing. Superior resource efficiency proven through major flagship projects, and publicised.
10 Years (2033)	Smart Building has demonstrated a 50 - 80% reduction in waste and carbon on the way to net zero and UN Sustainable Development Goals.

Resource and energy efficiency (through-life operation) challenge

Now	Australians are high adopters of rooftop solar. However existing building codes allow structures to be energy- and water-inefficient over their lives.
3 Years (2026)	Growing awareness of prefabrication's potential for higher operational resource efficiency, and connection to ongoing affordability. Awareness of potential to use digital technologies and good design to achieve through-life energy and resource savings.
5 Years (2028)	Superior resource efficiency proven through major flagship projects, and publicised.

10 Years (2033)	Prefabrication preferred for its superior resource efficiency both in production/construction and through-life operation. Production of 10-star energy rated buildings and homes commenced in 2030 and is now growing. Smart Building has demonstrated a minimum 20 percent prefabrication life cycle cost advantage over conventional.

Carbon reduction (production, embodied) challenge

Now	Conventional and prefabricated high in embodied carbon. Conventional building high wastage rates, adding to carbon.
3 Years (2026)	Plans to develop responsible steel, aluminium, timber and, to a lesser extent, concrete.
5 Years (2028)	Use of responsible steel and aluminium commencing. Use of prefabricated timber components rising as low carbon methods are demanded. Growing awareness of lower carbon footprint of Smart Building. DfMA used as the digital source of truth about carbon footprint of all materials used and of the whole building.
10 Years (2033)	A Smart Building industry on the way to carbon neutrality. Smart Building has demonstrated a 50 - 80% reduction in embodied carbon on the way to net zero and UN Sustainable Development Goals. Smart Building has demonstrated a clear carbon advantage over conventional construction. Responsible steel increasingly used. Production of 10-star energy rated buildings and homes commenced in 2030 and is now growing.

Production & technology challenge

Now	Offsite largely uses existing production techniques; yet to embrace digital to transform production and create new products. Most are digital outsiders or beginners.
3 Years (2026)	Dedicated national program. Production changing: greater offsite, and greater use of digital production. More digital beginners and more intermediates who had earlier been beginners.

5 Years (2028)	Digital production and assembly fully embedded in industry leaders, with positive spill-overs to less advanced firms. There are more digital intermediates, and experienced digital players. There are also more digital beginners with plans to advance. Awareness is growing of digital applications not only to production, but to new digital products. Digital enhances work rather than replaces workers.
10 Years (2033)	Digital production and assembly is now the norm. Digital is applied not to replace workers, but to collaborate with a more highly skilled workforce at all levels. The value chain is led by digital expert businesses. More businesses are making digital products bundled with ongoing services for climate and energy efficiency, ageing support, etc. 80% of building elements (facades, structures, wet areas and services) manufactured off site in smart factories – the preferred construction methodology for the built environment. Digital integration on all projects - automated design, AI - the industry standard leading to increased delivery innovation and continuous improvement.

Workforce challenge

Now	Huge demographic pressures and very poor housing affordability. Resumption of immigration and population growth creates additional construction demand against constrained supply. 8 percent of the construction workforce exits the industry each year, and almost half a million new construction workers will be needed in the five years to November 2026.
3 Years (2026)	Workforce strategy agreed and operating. Productivity and attraction and retention have become central to a robust workforce strategy, incorporating the growth of Smart Building and its distinct skills requirements.
5 Years (2028)	Women workers are increasingly attracted to the offsite work environment. Young workers are increasingly attracted by greater opportunities to use digital skills, tools and technologies.
10 Years (2033)	Our industry is the preferred employer for diversity, equity, inclusion and women friendly. Our industry uses digital technologies and applications to attract young workers.

Embed DfMA challenge

Now	Capability exists, but currently in limited use. Difficulties in getting BIM and DfMA systems to speak to each other. Critical to prefabrication and Smart Building, as well as Green and Circular Economy objectives. Need for industry education program.
3 Years (2026)	Dedicated industry education program. DfMA starts to be a prequalification requirement for major projects.
5 Years (2028)	DfMA is increasing in response to rising demand for Smart Building. DfMA is applied widely as a prequalification condition for major projects, and applied across the value chain.
10 Years (2033)	DfMA is the industry standard. Digitalisation and Design for Manufacturing & Assembly: Digital integration and DfMA on all projects - automated design, AI - the industry standard leading to increased delivery innovation and continuous improvement.

Embed Smart Building in key major projects challenge

Now	Interest and some program and procurement initiatives at state level. No national policy commitment, but important initiatives such as NRF (reindustrialisation) and NHA.
3 Years (2026)	Explicit national policy commitment, with targets and vision, dovetailing with state policies. Development of supporting state policies, dovetailing. Targets focus on the NHA and high-profile projects, such as Olympic Games infrastructure and works announced on cancellation of the Melbourne Commonwealth Games. Advanced public procurement principles.
5 Years (2028)	Policy now delivering scale and major demonstration effects.
10 Years (2033)	Mature demand-driven system creates virtuous cycle of innovation, affordability, inclusiveness and environmental and climate sustainability. Strategic public procurement favours Smart Building: Starting with the NHA and the 1.2 million new homes commitment, prefabrication and Smart Building provide the majority of all public sector construction by 2033. In 2030, the final year of the NHA, prefabrication and Smart Building accounted for more than 50 percent of the 2030 build.

Building scale, public procurement challenge

Now	Little use of strategic advanced procurement for industry development, or as industrial policy.
3 Years (2026)	Principles of advanced public procurement for Smart Building adopted by Commonwealth and state governments, with many large local governments on board. Includes prospective 3-, 5-, 10-year rolling project horizon, allowing industry to prepare. People trained in procurement; projects and components identified and scoped.
5 Years (2028)	Principles of advanced public procurement for Smart Building embedded and institutionalised. Delivering visible benefits.
10 Years (2033)	By organising and coordinating demand-side, market-shaping forces, advanced public procurement has helped create and expand a sector of significance for Australia's economy, society and environment. Starting with the NHA and the 1.2 million new homes commitment, prefabrication and Smart Building provide the majority of all public sector construction by 2033.

National strategy/policy, Smart Building sectoral program, leadership development challenge

Now	Some state programs and applied research, but no explicit policy or program recognition nationally (despite clear complementarities). But a focus on Smart Building and industry leadership is emerging.
3 Years (2026)	Smart Building is explicitly recognised in national and state industrial policies, which are dovetailed and coordinated. Focus on digital adoption all along the value chain and addressing weaknesses in Production and Assembly particularly. Industry leadership based on agreed directions is growing.
5 Years (2028)	Industry capacity and capability are growing in line with higher demand. Production and Assembly capabilities especially are being enhanced.
10 Years (2033)	Australian Smart Building constitutes a coherent, dynamic value chain. Flagship projects have created benchmarks and baselines demonstrating Smart Building's superiority. By the final year of the NHA (2030), prefabrication and Smart Building account for at least 50 percent of the 2030 build. The Olympic Games has been a major demonstration of the benefits and superiority of Smart Building.

Ecosystem changes challenge

Now	Australia has several factories of the future, mainly linked to universities. They are largely fragmented and do not relate to a national mission or system of innovation.
3 Years (2026)	Selected future factories in each state now linked and coordinated, with mission to supply knowledge services to develop the Smart Building sector (Prefabrication Innovation Hub).
5 Years (2028)	Coherent industry clusters are taking shape, and fragmentation is reducing.
10 Years (2033)	The network of future factories (Prefabrication Innovation Hub) is well-led and coordinated, providing high-quality industry development advice and services, in line with the strategy.

Attachments

Attachment 1: The Size of the Prize: Macroeconomic Gains from Smart Building

Australia's construction sector contributed just under $153 billion to GDP in 2022[54]. Estimates of prefabrication advantages over conventional vary from a 20 percent cost reduction, to a dramatic five-to tenfold productivity gain, from a strong mass production manufacturing approach, utilising high standardisation, modularisation and off-site production.

If we achieve the Roadmap target for prefabrication to constitute 30 percent of construction output by 2033, and assuming cost savings of 20 percent are achievable by the end of the Roadmap decade (2033), construction sector cost savings would amount to $9 billion annually. This figure represents current (2022) prices and given the uncertain outlook for inflation, no attempt is made to inflate this figure to a projected 2033 level.

Conventional construction is noted for low productivity together with high rates of resource inefficiency. Prefabrication's productivity advantages issue particularly from its ability to deploy digital technologies across production and the entire value chain, and also include:

- Reduced project schedules and overheads
- Reduced materials consumption and wastage
- Fewer intermediaries
- Savings delivered by factory organisation
- Other factors.

These advantages may be offset or reduced by factors such as logistics costs. And realisation of these advantages requires economies of scale.

The five- to tenfold productivity gain would be an ambitious goal, dependent on very thorough and extensive adoption of prefabrication across the construction sector.

Although achieving the 20 percent cost reduction is not an easy task, requiring significant investment, this is a conservative estimate of benefits.

Here are some of the reasons for considering this a conservative estimate.

It is an estimate of cost savings only, achieved through reduced inputs. Achieving these cost reductions provides the initial impetus to businesses, governments and buyers to consider Smart Building.

In addition, however, productivity benefits accrue as industry scale and the market grows, allowing lower unit costs. Productivity grows with the size of the market and sustained high output.

Once economies of scale are achieved, enterprise productivity is also enhanced through learning by doing and the development of dynamic capabilities. There are positive effects associated with new innovations affecting processes, business models, development of new products, etc.

Finally, savings made have second-, third- and fourth-round effects that flow through the economy to increased consumption and investment.

Only the effect of cost-reduction is considered to arrive at the annual $9 billion economy-wide benefit. This is only part of a larger productivity story.

The annual cost saving would ideally be shared between affordability gains and improved industry bottom lines.

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54 ABS, Australian System of National Accounts, Table 5, Gross Value Added (GVA) by Industry, Catalogue 5204.0.

Attachment 2: Smart Building Policies in International Perspective

Australia can learn from the policy experiences of other nations, to inform and accelerate its own progress toward Smart Building. The most important element of successful nations is the ambitious deployment of demand side drivers that build project scale as well as set challenges to drive improvement and innovation along the value chain. The principal demand-side lever is advanced public procurement, which might mandate a high proportion of smart building in new developments. Other important levers seek to change industry behaviour and shape the market and include regulations and standards which identify Smart Building with high quality.

In strong industrial countries such as Singapore, Japan, Germany and Sweden, the growth of a strong prefab sector is partly the consequence of regarding it as another industrial sector, as well as solving problems associated with climate resilience, resource efficiency, and housing supply and affordability.

The full array of positive policies comprises large scale procurement and land releases targeted to prefabrication; targeted sectoral programs and policies (e.g., UK Construction Sector Deal); support for resource efficiency; promotion of Industry 4.0 as conditional on specified use of prefabrication; Innovation- and Green-Public Procurement; and inspections and certification regimes that underscore quality and public confidence.

Germany:

- High adoption of Smart Building, with high proportion of individual purchasers specifying prefab
- High adoption rates of Industry 4.0, strong applied R&D networks like Fraunhofer
- Concern with green issues and resource efficiency.

Scandinavia:

- Very high rates of prefabrication, high use of abundant timber resource. Estimates of prefabrication share of total dwellings between 45 and 80%
- Strong use of regulation to promote green building.

Japan:

- Strong prefabrication push since the 1960s linked to overall industrial policies of the Ministry of International Trade and Industry (MITI). Strong spillovers into prefabrication from Japan's heavy industries like steel, chemicals, electronics, chemicals and automotive
- Strong consumer preference for prefab, with CAGR of 6% by 2027; high bundling of services (e.g., ageing)
- Inspections specifically for prefabricated codes underscore image of quality and promoting the movement of the industry up the value chain
- Long-term warranties for assured building performance.

Singapore:

- Housing Development Board building 20-30,000 offsite-constructed units per year
- Mandated use of volumetric modules in public projects (35% of projects)
- Building Construction Authority mandates volumetric modules for 65% of floor space in residential on specified sites
- Land releases to private sector conditional on level of prefabrication, and mandated in public sector projects
- Capital fund supports Construction Productivity Roadmap and Construction Industry Transformation Map
- Mandated use of DfMA.

UK:

- 2016 Farmer Review sought to increase prefabrication partly as a response to Brexit impact on migrant construction labour
- Government preference to prefab and level 2 BIM requirement
- Construction one of 5 nominated areas for resource efficiency ('Waste to Wealth')
- Dedicated P-DfMA – program to accelerate modular
- Grant program to unlock sites – conditional on use of modular, with focus on combining prefab and digital
- Construction Sector Deal promoting offsite construction and digital technologies and emphasizing whole of life cost advantages, waste reduction and increased productivity
- Digital Built Britain – promotes effectiveness and efficiency over a building's life cycle through BIM and advanced data analytics
- Build Offsite Property Assurance Scheme (BOPAS) helps secure finance through audit and accreditation regime for product quality and assurance of 60-year durability.

Australia:

- State policies in SA, NSW and especially Victoria (Permanent Modular Schools Program; Dept of Health and Human Services program); some targets in major projects such as Olympic Games village
- PrefabAUS, Building 4.0 CRC, AMGC, the Prefab Innovation Hub, universities
- Asia-Pacific Research Network for Resilient Affordable Housing, ARC Centre for Advanced Manufacturing of Prefabricated Housing (UoM)
- NRF touchpoints to Smart Building for future development; 1.2 million new homes commitment.

List of Abbreviations

- BCA: Building Code of Australia
- BIM: Building Information Modelling
- BOPAS: Build Offsite Property Assurance Scheme
- CAGR: Compound Average Growth Rate
- CLT: Cross Laminated Timber
- DfMA: Design for Manufacture and Assembly
- DLT: Dowel Laminated Timber
- ECI: Early Contractor Involvement
- EPDs: Environmental Product Declarations
- GECA: Good Environmental Choice Australia
- GLT: Glue Laminated Timber
- LVL: Laminated Veneer Lumber
- MTC: Mass Timber Construction
- NCC: National Construction code
- NHA: National Housing Accord
  - HAFF: Housing Australia Future Fund
  - NHIF: National Housing Infrastructure Facility
- NLT: Nail Laminated Timber
- NRF: National Reconstruction Fund
- SMEs: Small and Medium Enterprises
- TLS: Through-life Support


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